The Italian National Seismic Prevention Program

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SUMMARY:
After the destructive Abruzzo Earthquake of April 6, 2009, almost one billion euro in seven years were allocated for seismic prevention by the Italian Government. This amount is just a small fraction of what is actually needed, nevertheless a wide-spectrum national plan for seismic risk mitigation has been implemented. The primary objective of the plan, whose strategy and supervision is in charge of the Italian Civil Protection Department, is to reduce human losses, so that the action is especially addressed to high hazard and high risk areas. It is implemented not only through the seismic upgrading of structures, to produce the immediate reduction of the seismic risk of the retrofitted constructions, but also through the evaluation of the local seismic hazard and the seismic resilience of urban systems, according to a more integrated and prospective strategy for seismic risk mitigation. In the paper, a comprehensive review of the risk mitigation activities until 2009 and a thoroughly description of the prevention strategy and actions of the new national plan are provided.

Keywords: Risk, Prevention, Strategy, Strengthening, Microzonation

1. INTRODUCTION

The seismic history of the Italian territory highlights awful losses in terms of casualties and huge social and economical costs. In summary (Dolce, 2009b):

- Since 1000 A.D. 220 events occurred with epicentral MCS intensity ≥ VIII.
- In the past two centuries earthquakes with magnitude between 5.5 and 7.2 caused about 150,000 casualties; moreover, they damaged and/or destroyed a considerable part of the Italian historical and cultural heritage, whose value is not quantifiable.
- In the last 50 years, earthquakes with magnitude between 5.5 and 6.9 caused monetary losses for over € 150 billion.

Even considering the present situation of the building stock and the possible occurrence of future earthquakes according to the rate of earthquakes in the past centuries (Dolce, 2009b), expected costs are of the order of € 2-3 billion per year and are then in line with the expenses of the last 50 years. All above emphasises the disproportion between the potential destructiveness of earthquakes, expressed through their magnitude, and the actual consequences. This situation can be ascribed to several factors, among which the obsolescence of many buildings, the late seismic classification of the territory, the high seismic vulnerability of the historical centres and of the huge Italian cultural heritage deserve mentioning.

Like in other countries with high exposure of the population and high vulnerability of the constructions, a huge effort would be necessary to mitigate seismic risk. In a broad sense, seismic risk mitigation requires different and parallel lines of action to be pursued, that can be summarised as:

1. Improvement of the knowledge,
2. Reduction of the vulnerability and exposure,
3. Mitigation of the effects.

The first line is essentially related to the technical-scientific knowledge on seismology, earthquake engineering and any other matter that can be useful for analysing seismic risk, as well as to the knowledge of the territory - namely local hazard, construction characteristics, population distribution, socio/economic activities - needed to set up effective risk mitigation strategies and translate them into consistent practical actions.

The second line is related to the indirect and direct actions that are aimed, respectively, at a prospective and an immediate reduction of vulnerability and exposure.

Indirect actions are mainly relevant to the improvement of tools for seismic design - such as hazard maps, seismic code and seismic classification - and for urban development and emergency management - such as seismic microzonation, urban and emergency planning.

The third line is related to a general growths of the culture of civil protection, which is implemented through the communication on the correct behaviour of people, before, during and after an earthquake, the improvement and practical implementation of civil protection plans, the preparedness and the prompt response of the population and of the civil protection system, especially through exercises aimed at the practical verification of local and national emergency plans.

In spite of the enormous expected losses, seismic prevention remains, however, a difficult objective to fully achieve, due to the high costs implied, the long time needed to achieve objectives, the little sensitivity of the public opinion and, consequently, the scarce interest of the political leadership.

The situations changes after a destructive earthquake, such as it happened even in the recent past after the 1980 Irpinia Eartquake, the 1990 Eastern Sicily Earthquake, the 1997 Umbria/Marche Earthquake, when some seismic risk mitigation measures were taken, mainly consisting in the improvement of seismic code and classification, but with little economic effort to directly reduce the vulnerability in areas not interested by the recent earthquake. Only after the 2002 S.Giuliano Earthquake, an attempt was made to implement a more comprehensive strategy for risk mitigation, including not only the updating of the design tools (seismic classification and code), but also the improvement of knowledge and some direct actions for vulnerability reduction.

This effort has been renewed and readdressed after the April 6, 2009, Abruzzo Earthquake. In the Law 77/2009 for the reconstruction in the damaged areas, two articles are instead devoted to the seismic prevention in the whole national territory: article 1bis establishes the immediate enforcement of the new technical standards promulgated at the beginning of 2008, while article 11 allocates almost one billion euro for the seismic prevention, to be spent in the following seven years. This amount is just a small fraction of what is really needed to solve the problem of seismic risk in Italy and less than half the expected average annual cost of earthquakes. Nevertheless the allocated funds will be employed for a wide-spectrum national plan for seismic risk mitigation, which will be implemented through direct and indirect actions for the reduction of the vulnerability and exposure. Meanwhile the other two lines action will continue to be pursues by the Civil Protection Department, according to previously set up programs.

The primary objective of the plan is explicitly stated to be the reduction of the expected human losses, rather than economic losses, so that the action is especially addressed to high hazard and high risk areas.

Direct prevention actions will consist of the seismic upgrading of structures, in order to produce an immediate reduction of the seismic risk of vulnerable buildings and infrastructures in high seismic hazard areas. Public and private buildings as well as bridges and viaducts along routes fundamental for local emergency plans are the objects of these actions.

Indirect actions will consist of the improvement of the knowledge of the local seismic hazard and of the seismic resilience of urban systems. Seismic microzonation studies are, indeed, funded, in order to improve urban and emergency planning. They must be carried out according to the 2008 Italian Guidelines for microzonation (MS Working Group, 2008). It is envisaged that in few years the urbanized territories of all the municipalities in medium and high seismic hazard areas will be endowed with microzonation studies. In the meanwhile the assessment of the so called "limit condition for emergency" of urban systems is introduced and incentives are provided for that. It essentially consists of the assessment of the vulnerability of the strategic elements and of the fundamental routes in the local emergency planning, as well as an evaluation of the system performance. Indirect actions are also addressed to raise risk awareness of citizens and local administrators.

The paper describes past and present seismic risk mitigation activities in Italy, trying to explain both the general strategy and the practical implementation of the actions. A special attention is devoted to the national plan in progress, established in 2009, since the integrated approach which is being implemented appears to introduce some interesting novelties for a more comprehensive and effective offensive against seismic risk.

2. PAST SEISMIC RISK MITIGATION ACTIVITIES IN ITALY

The activities carried out in Italy for seismic risk mitigation in the last 30~35 years, until 2009, are described according to the lines of action summarised in the introductory paragraph.

2.1. Improvement of the knowledge

The growth of the scientific knowledge and the improvement of the knowledge of the territory have been the object of much attention by the Civil Protection Department. Several applied research programs have been funded for 35 years, involving the whole scientific community (Dolce, 2008). A strong impulse has been given to research areas that, otherwise, would not have had significant chances of improving so rapidly. In the first phase, until 2003, the results of these activities can be summarised as a widespread general growth of the scientific knowledge in both the seismological and the earthquake engineering fields and a progressive development of a systematic approach to the assessment of seismic hazard and seismic risk, to the design of new constructions and to the retrofit of the existing ones. However, only part of the research products could be immediately finalised and many of them just testify the improvement of knowledge on the concerned aspects.

After the 2002 S.Giuliano Earthquake it was understood that the research activities had to be better oriented and finalised, in order to meet the actual needs for the prevention actions. For this reason the seismological and earthquake engineering scientific support to DPC was re-organised, so that it is now provided mainly by three Competence Centres for Seismic risk: INGV, the National Institute for Geophysics and Volcanology, ReLUIS, the network of research laboratories of earthquake engineering, EUCENTRE, the European Centre for Training and Research in Earthquake engineering.

INGV is also the institution which has in charge the seismic surveillance of the Italian territory, implementing and managing the national DPC-INGV seismometric network, which was significantly improved in the last ten years, to comply with the growing exigency of immediate and correct evaluation of earthquake parameters.

The two Competence Centres for earthquake engineering, ReLUIS (www.reluis.it) and EUCENTRE (www.eucentre.it), have a strong attitude towards the experimental research and the training of young scientists and professionals. The experimental work, indeed, has always been the weak point of the earthquake engineering research in Italy, due to the lack or inadequateness of the facilities. In the last decade, however, four university laboratories have been renewed and/or upgraded: University of Naples “Federico II”, University of Basilicata - Potenza, University of Pavia and University of Trento. They have founded the ReLUIS consortium to work together in a laboratory network and involve other universities in their experimental activities.

The EUCENTRE foundation is an international reference centre for both research on seismic risk and training, also due to the synergy with the international Rose School. EUCENTRE manages and implements the large lab facilities available at the University of Pavia, partly funded by DPC.

Scientific projects of the competence centres are funded by DPC, on a three-year contract basis. Their objectives are oriented, and relevant activities are monitored, by DPC, in order to finalise scientific results towards products of immediate interest for Civil Protection purposes. Scientific projects carried by INGV and ReLUIS (e.g. see Manfredi, Dolce, 2009) involve a large number of researchers, in all the Italian universities and institutions with high qualifications in seismology and earthquake engineering research. This large involvement has been fundamental to get results of high scientific value and widespread consensus in the scientific community, allowing seismic hazard assessment and seismic code to make considerable step ahead in the last decade.

As far as the knowledge of the territory is concerned, several actions have been carried for its improvement during the last decades. They are necessary for the evaluation of the funds globally needed or relevant to single categories of constructions and single portions of territory, so that risk mitigation strategies can be compared and concrete actions undertaken. According to their accurateness, evaluations are also necessary to establish priorities among existing constructions of the same type or among groups of constructions. They are also useful to make public administrators more aware and sensible to the seismic risk problem. The most important actions are related to the public and the private building stocks and to the seismic microzonation of the built areas.

The knowledge of the characteristics of the public buildings is aimed at evaluating their seismic vulnerability and risk. In Italy different types of investigation, at different levels of definition and accuracy, were and are being carried out on the national territory or on significant portions of it. The most important ones are:

- The LSU (Socially Useful Works) project, that was carried out in 1996 on all the public buildings in Southern Italy - which is the part of Italy with the highest hazard and about 2/3 of the overall seismic risk - by unemployed technical personnel;
- The provisions of the Ordinance 3274, passed on March 20, 2003, after the S.Giuliano Earthquake, that require the seismic verification, according to the seismic code, of all the buildings and infrastructural constructions of strategic importance, i.e. whose operability during and after seismic events is fundamental for the civil protection activities (e.g. hospitals), as well as those of great importance in relation to the consequences of their collapse (e.g. schools), within five years, now delayed until the end of 2012.

The LSU survey was aimed at collecting the most important features of buildings related to their vulnerability and their use, through visual inspection. The vulnerability and the seismic risk of each building could then be evaluated from the collected data (Cherubini et al. 1999). These evaluations are statistically reliable, and are then extremely useful to get an overall picture of the needs for a seismic prevention program at national level and to establish priorities at regional level. However they cannot be reliably used for individual buildings. 40,477 buildings (20,887 school buildings) were surveyed in 1511 municipalities, by 774 technical operators.

The Ordinance 3274/2003 was aimed at getting an exact evaluation of the seismic safety of the constructions which are strategic or important for the consequence of their collapse, to establish priorities and set up local and national mitigation strategies. In order to favor and speed up the process, the Law 326/2003 allocated a fund of € 200 million to make both verifications and upgrading interventions. € 83 million allowed 7000 seismic verifications to be carried out, among which 2,400 school buildings (Dolce et al. 2007b). This is supposed to be approximately 10% of the total number of buildings all over Italy to be verified, i.e. buildings designed with no or inadequate seismic provisions, 35,000 of them being located in zones 1 and 2. Even at present the number of safety verification is still quite far from the total requested number and the process to start and complete these verification is indeed very slow. A recent initiative of DPC is aimed at getting at least a complete list of the constructions to be verified, in order to make a realistic program for the completion of the verification, since there is at present no possibility of further funding them. On the other hand it must be said that the most important Italian companies that own and manage the highway system and the railway system have completed or at least initiated their seismic verification plan.

The positive aspect of the safety verifications is that they will certainly result in the enhancement of the awareness of politicians, public administrators and decision makers about the seismic deficit of most of the existing constructions and the need to increase the attention to the problem and devote larger funds to implement effective seismic mitigation policies. However some further considerations should be made, highlighting some negative aspects. The increase of the "awareness of the risk" for the public administrators directly involved could rather result in the "risk of the awareness", as soon as the lack of safety is revealed by the outcome of a safety verification according to the seismic code. Although neither the code nor any law oblige the owner to take immediate countermeasures in case of seismic inadequateness (like immediate interruption of the use of the construction), the public pressure (e.g. in case of unsafe schools), as well as the worry for any prosecutors' action in case of damage or collapse consequent to an earthquake, create a difficult situation to be managed by public administrators. These latter could therefore incline to avoid this "risk of the awareness", also because of the general lack of funds for both carrying the verification and making the upgrading interventions needed. Moreover, it must be remarked that often safety verifications are carried out by making very conservative assumption (e.g. using elastic analyses and conservative strength values). Very often the actual strength and ductility capabilities of the structure are not fully exploited in the safety verification, depending on the skill or simply the will of the professional in charge.

As far as private buildings are concerned, their seismic risk is evaluated at national level by using the data drawn from the population census carried out every 10 years. An agreement of DPC with the National Institute for Statistics (ISTAT) allows DPC to get uniform and complete exposure data on the population and on the private building stock, all over the national territory. Obviously, they provide quite poor information on the characteristics of the buildings, just limited to age, number of stories and type of structure - reinforced concrete or masonry. Seismic risk is then evaluated by DPC as well as by the competence centers, using different criteria and algorithms.

Extensive surveys by visual inspection of damaged and non damaged buildings were also carried out after all the recent destructive earthquakes in Italy, providing precious data bases to calibrate the vulnerability functions of different building types that can be found in the Italian territory. Damage data, along with their structural characteristics, have been collected on some hundreds of thousand buildings since 1976. ReLUIS (Liberatore, 2009), as well as the National Group for the Defense against Earthquakes (GNDT) in the past (Zuccaro, 2004), have also carried out surveys on samples of building stocks, in order to calibrate the specific features of buildings and thus improve the vulnerability estimations based on the ISTAT census.

The competence centers are also contributing to the improvement of knowledge on the seismic risk of the Italian territory, not only by making preparatory studies, but also by setting up tools and using them in order to make an evaluation of the seismic risk of the school system as well as the highway and road transportation systems, whose validity is again at a statistical level. To be mentioned are also the tools and studies on the seismic resistance of harbors and earth dams, made by EUCENTRE (e.g. Bozzoni, Lai, 2012).

As far as the improvement of the knowledge on the local hazard are concerned, almost all of the microzonation studies were carried out, until few years ago, after destructive earthquakes, mainly in the epicentral areas, as a tool for the reconstruction activities. This has occurred since the 1976 Friuli Earthquake. Only recently in few Regions, microzonation studies have been carried independently of the occurrence of earthquakes, as preventive tools for urban and emergency planning.

2.2. Reduction of the vulnerability and of the exposure

In the past, direct actions of seismic prevention were essentially made after major earthquakes, in the damaged areas on damaged constructions. Indeed, besides being repaired, they were also strengthened with the financial contribution of the State, covering in most cases all the costs (Di Pasquale et al., 2007). Therefore the areas that in the last 50 years were struck by earthquakes have undergone a substantial mitigation of their seismic risk, while there are few vulnerability reduction activities initiated in areas different from the ones struck by a strong earthquake or however concerning undamaged buildings.

The most recent example of such an approach in a post-event reconstruction process is the 6 April 2009, Abruzzo Earthquake (Dolce, 2009a), where a clear distinction was made between reimbursement for repair and for strengthening. For private buildings the amount of reimbursement for repair works is calibrated on the state of damage and on the assessed usability state (Dolce et al., 2009c). The reimbursement is then regulated as follows:

1. Maximum reimbursement of € 10,000 plus € 2,500, for common parts, per apartment for repair of "A" usable buildings (no or very slight damage);
2. Full reimbursement of repair works, plus € 150-250 per square meter for the local strengthening (of critical structural and non structural elements) of "B", "C" buildings and "E" buildings with slight structural damage;
3. Full reimbursement of repair works, plus € 400-600 per square meter, for the seismic retrofit of "E" (severely damaged buildings).

Focusing on the seismic strengthening of undamaged buildings, some of the rare examples before 2003 funded by a State law are in Tuscany (Garfagnana), Law n. 730 of 28 October, 1986, Calabria, Law n. 400 of 3 October, 1987, Eastern Sicily, Law n. 433 of 31 December, 1991, Basilicata, Law n. 195 of 3 July, 1991. Seismic retrofit concerned mainly public buildings, especially schools. Only in Eastern Sicily a small part, amounting to about € 66 million, of the total investment was devoted to private dwelling buildings. In 1997 - Law n. 449 of 27 December, 1997 - incentives for the seismic upgrading of private buildings, consisting in a 10% reimbursement, were established in the Italian municipalities with the highest seismic risk. However this measure did not produce significant effects. The total State investment on structural prevention in areas not recently struck by earthquakes between 1985 and 2003 was € 316 million.

Things changed after the 2002 S.Giuliano Earthquake, when a series of actions concerning the improvement of the knowledge and the reduction of the vulnerability and the exposure were undertaken: besides establishing the competence centres for seismic risk, making a plan for seismic verification of strategic and important constructions and allocating funds for strengthening and verification of constructions, a new code and seismic classification were promulgated and, above all, funds for strengthening strategic buildings and schools were allocated.

Obviously schools deserved a special attention, because of the collapse of the school of S.Giuliano and the death of 27 children. For this reason a special program for their seismic safety improvement was enforced. About 42,000 public schools exist in Italy. About 26,000 of them are located in seismic zones 1, 2 and 3. Their retrofitting costs are of the order of several billions euro. The initial program was funded in 2003, with an allocation of about € 500 million, resulting in about 1600 seismic upgrading interventions.

With the already mentioned Law 326/2003, € 200 million were allocated for seismic retrofit and seismic verifications of constructions. 230 retrofit interventions were financed in the years 2004 and 2005. Starting from 2008, with the same law an annual fund of € 20 million was dedicated exclusively to the seismic retrofit of school. This program is still in progress and permits to retrofit about 50 school buildings per year with the State contribution, cofinanced by local administrations.

In total, between 2003 and 2009, about € 750 million were allocated for seismic retrofit interventions of public buildings.

As far as seismic classification and seismic code are concerned, the by-law 3274/2003 was decisive in making a considerable step ahead in Italy. The previous seismic classification was made soon after the 1980 Irpinia Earthquake, and included about 45% of the Italian territory in zone 1, 2, 3. After about 20 years considerable knowledge improvements were achieved and it was really indispensable to update the seismic classification. Moreover, since S.Giuliano and other municipalities in the epicentral area of the 2002 earthquake were not classified, it was deemed necessary to introduce the zone 4, where all the remaining areas of the Italian territory not belonging in zone 1, 2, 3 had to be classified. With the new classification, about 70% of the territory was in zone 1, 2, 3, and the remaining 30% in zone 4. In 2006 a new national seismic hazard map was produced and a new classification have been adopted.

Similar considerations can be made about the seismic code. Before 2003, the Italian seismic code was practically still based on principles and criteria developed in the seventies. With the Ordinance 3274/2003 a totally new code, derived from the Eurocode 8, was drafted, but it was not fully enforced. Indeed it could be used on a voluntary basis for many years. Important aspects dealt with in that code are the seismic upgrading of existing constructions and the use of seismic isolation for new and for existing constructions. In the following years new standards were set up by the Ministry of Infrastructures in 2005 and 2008 (Minister of Infrastructures, 2008), whose seismic parts were essentially based on the 2003 seismic code. However their compulsory use was again delayed. The 2008 code introduced some important novelties which are of great importance for the retrofit of existing buildings, among which: the direct use of the seismic hazard maps (OPCM 3519/2006) for the evaluation of the design actions, rather than the four levels of seismic actions corresponding to the seismic classification, and the introduction of the local strengthening of structural parts or elements as an effective design tool for seismic upgrading.

Among the indirect actions aimed at improving the tools for design and planning, a special mention is deserved by the approval of the ICMS08, "Guiding principles and Criteria for Seismic Microzonation" (MS Working Group, 2008), on November 11, 2008, by the Conference of Italian Regions and Autonomous Provinces and the Civil Protection Department. Seismic Microzonation (SM) studies identify and characterize stable areas, stable areas susceptible of local amplifications and areas subject to instability, such as landslides, superficial breaks due to faults and dynamic soil liquefactions. They provide information useful for the territory management, for the emergency planning, for the post-earthquake reconstruction and for the structural design.

The drafting of the ICMS08 (MS Working Group, 2008) involved over 100 experts coordinated by DPC. ICMS08 describes the principles and elements of the SM and how to use it in land planning, emergency planning and seismic design of constructions. According to ICMS08, SM studies may be carried out at various levels of growing complexity and commitment, from level 1 to level 3, depending on the contexts and objectives:

- Level 1 has the objective of identifying zones with homogeneous seismic behavior on a map at a scale of 1:5,000 or 1:10,000. It represents a preparatory and mandatory study for the subsequent levels. The results of this level may guide the choice of the next level of study (level 2 or level 3). Only in particular cases may the results of this study be regarded as exhaustive and final.
- Level 2 associates quantitative elements to the homogeneous zones, by using simplified methods and additional and focused investigations - where necessary. The investigations are basically geophysical, such as seismic refraction tests or instrumental analyses with active and passive techniques for the estimation of Vs, measurements of microtremors and seismic events. When possible, depending on the resources available, Down Hole or Cross Hole investigations are done. Through correlations and comparisons with the results of level 1, it is possible to review the geological model and process a map of SM which quantify the effects in seismically-homogeneous microzones.

- Level 3 defines and characterizes the zones prone to amplification or instability, by solving the complex geological and geotechnical situations, such as reversals of Vs, which cannot be solved with abaci or simplified methods used for level 2. It requires an important commitment of economic and professional resources, which is justified, for instance, in the phase of post-earthquake reconstruction, but also, at an early stage, in the areas with high seismic risk. The investigations will consist of surveys to collect seismometric data, boreholes, in-hole and surface tests to determine Vs, in-situ and lab geotechnical tests (both static and dynamic), surveys of microtremors, necessary for a reliable model of the subsoil. The computations will include numerical 1D and 2D analyses to quantify local amplification and dynamic analyses of slope instability and liquefaction susceptibility. At this level, the paleo-seismological study of active and capable faults is typical.

All the microzonation studies which are being carried out now in Italy comply with the ICMS08. This will assure minimum quality standards and the homogeneity of the studies carried out in different territories and by different professionals, thus permitting an easy comparison among them. The first important test for the ICMS 08 was made in Abruzzo, soon after the earthquake of 6 April 2009 (Dolce, Naso, 2009). Important hints were drawn from that experience which are now implemented.

2.3. Mitigation of the effects

DPC has always cared the growth of the awareness of the seismic risk of the population and of the decision makers, and has always been very active in making the culture of prevention and civil protection to grow up. Several books dedicated to the strongest earthquakes in the past, also in cooperation with external researchers, have been written, in order to refresh the memory and understand the multifaceted aspects of seismic risk. Furthermore, leaflets containing friendly explanation of seismic risk and behaviour rules in case of earthquake have been produced and widely distributed, with the cooperation of the competence centers. It has also promoted and participated to several information campaigns in Italian schools, carried out at national level by NGOs, and funded specific activities carried out by INGV. In the last five years a travelling exhibition called "Terremoti d'Italia" (Earthquakes of Italy) has been taken in about twenty Italian towns and even abroad. The most appealing section of the exhibition includes equipments for the simulation of earthquake effects: a 4.40 by 2.20 tri-directional shaking table able to reproduce real earthquakes, where 10-15 persons can feel the motion of the ground or of a floor of a building, and a 4m by 2m bidirectional shaking table supporting 10 fibreglass building and bridge models, excited with an earthquake-like motion. Until now, about 200,000 people have visited the exhibition.

A fundamental task of the national and local Civil Protection organisation is the preparation and actual implementation of emergency plans at different territorial levels. A specific care is devoted not only to the drafting of the emergency plans, but also to the organisation of exercises, at international, national and local levels, although the frequent occurrence of earthquakes in the recent years has limited the activity related to national and international exercises. Recent international exercises on seismic risk were carried out in Eastern Sicily (EUROSOT 2005) and Tuscania (TEREX 2010). They were aimed at testing both the command chain and the capabilities of the operational structures (VVF, Army, Police, Red Cross, voluntary organisations) at local, national and international levels, also by verifying their roles, their interconnections, their coordination.

More recently, the activity for emergency plans at the national level are essentially aimed at setting up the main lines of actions in order to coordinate effectively the National Seismic Service in the specific context considered, to identify the main strategic elements for the coordination at national level and the main transportation routes for reaching the hypothetically damaged areas. The basis of these plans are not a single scenario, but, more generally, the overall hazard, while single scenarios are used to check the plan essentially through table top exercises.

3. THE 2010-2016 NATIONAL SEISMIC PREVENTION PROGRAM

Strong destructive earthquakes have always brought on important improvement in the national policy for seismic mitigation, besides forcing the governments to invest considerable amount of money for the reconstruction. As said above, the most common and typical provisions for seismic prevention at national level taken after an earthquake were the updating of the seismic code and of the seismic classification, based on the recent lessons learned and on the scientific advancements which were not put into practice until the event. The same occurred after the 6 April 2009 Abruzzo Earthquake, with the Law by Decree n. 39 of 28 April 2009, converted by the Law n.77 of 24 June 2009. When the new technical standards of 14 January 2008 were promulgated, they were enforced only for strategic public buildings and infrastructural constructions, while its compulsory use for private and for ordinary public constructions was delayed until July 2010. In the Law 77/2009 it was stated that the new standards had to be compulsorily used for any kind of construction starting from the 1st of July, 2009, thus anticipating its full enforcement by one year, and avoiding any further postponement. Some important novelties were introduced in the new standards, that can improve the seismic prevention actions for existing constructions, as seen in a previous paragraph.

But what is much more important for the immediate and direct consequences in terms of prevention is the allocation of funds for the seismic risk prevention at National level provided with the article 11 of the Law 77/2009. The total amount is of almost one billion euro in seven years, namely 44 million for 2010 - which became 42.5 - and 2016, 145.1 for 2011 and 2015, 195.6 for 2012, 2013, 2014. The accomplishment of the prevention program is relied upon the Department of Civil Protection, which operates through Ordinances of the Prime Minister and Decrees of the Chief of the Department.

Evidently the total amount (exactly € 963.5 million), although significant with respect to the past, represents only a minimal percentage of what really needed, perhaps of the order of 1% or probably less. However, if adequately managed and communicated to the population, besides permitting to continue the seismic upgrading program started in 2003 with the Ordinace 3274, it can allow for considerable steps ahead through the implementation of new prevention tools and through the induced general growth of the culture of seismic prevention in the population and in the public administrators.

In order to define general objectives and criteria for a global and effective approach to the seismic risk reduction problem, a Commission of scientists and expert on seismic risk was established in January 2010, through the Ordinance 3843/2010.

The first objective for a risk mitigation policy, given the Italian generalised situation of unsafe structures, is the reduction of the expected human losses. In the current unfavourable economic condition, this objective should be pursued by concentrating the action in the areas where an earthquake can, with greater probability, produce the collapse of several buildings, and then essentially in zone 1 and 2 or, equivalently, where the expected peak ground acceleration is greater than a minimum threshold. In the same perspective, it appears necessary to provide private owners with incentives to strengthen their buildings. The history of Italian earthquakes, in fact, indicates that most of the casualties have occurred for the collapse of private dwelling buildings, where people spend most of their time. It is evident that the funds that can be dedicated to such objective are in any case not enough to solve the problem, but they can make the population more aware and sensible and initiate a virtuous process for a more widespread spontaneous action.

To summarise, the philosophy of the national prevention program is essentially based on:

- Pointing towards the reduction of the risk of human losses, rather than economical losses;

- Dealing with a wide spectrum of problems, then stimulating the attention of private owners and administrators towards the different problems of seismic risk (vulnerability of buildings, importance of local amplification and coseismic effects and use of microzonation studies to improve urban and emergency planning, correct implementation of civil protection plans considering the vulnerability of the strategic elements and of the interconnection routes);

- Asking for co-funding by local public administration and by private owners, in order to at least duplicate the actual effects of the allocated fund of the State.

It should be also underlined that most of the fund is aimed at direct actions, i.e. interventions for the seismic strengthening or the reconstruction of existing buildings, and not at evaluating the seismic vulnerability of existing construction. Funds for indirect actions are only limited to an integrated activity based on seismic microzonation and the study of the essential elements of the urban settlements, aimed at improving not only the knowledge of the local seismic hazard, but also the emergency management tools and planning.

The different actions are implemented through programs of the Regions and the Autonomous Provinces. A part of the total annual fund is assigned to each of them, in proportion to their seismic risk. The regional programs are defined according to the to the regional priorities, considering the requests of the municipalities.

The first two annual funds, i.e. those relevant to 2010 and 2011, for a total amount of about €187.5 million, have been regulated by the Ordinances of the Prime Minister 3907 and 4007, while a third Ordinance, relevant to the 2012 fund, is in the approval process.
According to the objectives and criteria expressed above, both ordinances identify the following 4 actions:

a) Seismic microzonation studies, funded with € 4 million and € 10 million for the 1st and 2nd year respectively, €14 million in total.

b) Interventions of seismic retrofit or reconstruction of buildings and infrastructural constructions of strategic interest or critical for the consequence of their collapse, with the exclusion of schools (whose strengthening is financed with other funds).

c) Interventions of seismic upgrading or reconstruction of private buildings.

d) Other urgent interventions to mitigate seismic risk, with particular reference to situations of high vulnerability and exposure, also related to public strategic structure or to assure the best implementation of civil protection plans. They are funded with € 4 million for both years, €8 million in total

The actions of points b) and c) are funded with € 34 million and 130 million for the 1st and the 2nd year respectively, €164 million in total. While the funding of private buildings was voluntary in the first year, it is compulsory in the second year, with a minimum of 20% and a maximum of 40%. The residual part of the funds are devoted to supporting activities carried out by the DPC with the assistance of the competence centres.

According to the stated principle that the primary objective is the reduction of the expected human losses, it is also explicitly stated that the contributions cannot be addressed to structures in municipalities where the 475 years return period PGA on stiff soil, a_g, is less than 0.125g (see Fig. 1).

The distribution of funds among the Regions is based on the seismic risk studies carried out by the competence centres ReLUIS and EUCENTRES and by the DPC itself. All these studies make reference to the same seismic hazard study made by INGV, within the DPC-INGV project 2004-2006, but use different vulnerability models, based on fragility curves drawn from mechanical models by EUCENTRE (Borzi et al. 2011) and on empirical damage probability distribution by ReLUIS and DPC (Goretti et al., 2008). The building and population exposure is drawn from the 2001 ISTAT census. The risk parameter considered, according to the general criteria stated above, is related to the human life losses, which obviously depends on the risk of collapse of buildings.

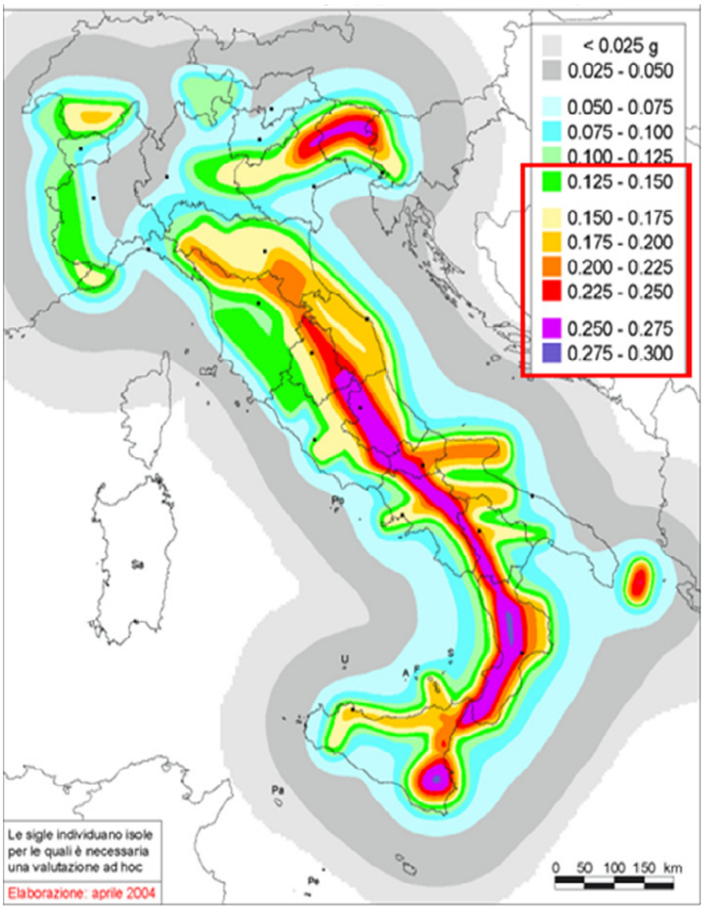
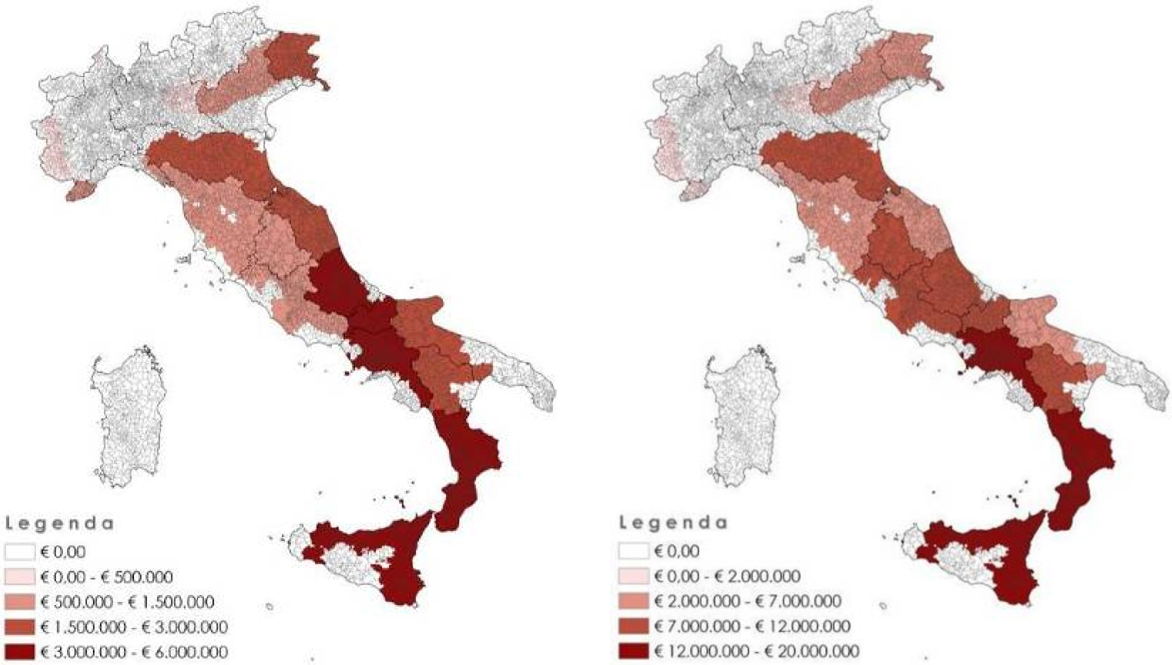


Figure 1. Official seismic hazard map of Italy, passed by the Ordinance 3519/2006.



a) 2010 **b) 2011**

Figure 2. Distribution of funds among the Regions relevant to the years 2010 and 2011.

The funds are assigned to the Regions in proportion to a regional risk index, which is calculated as a weighted average between two indices, both referred to the part of the Region with $a_g > 0.125g$:

- the specific risk index, providing a measure of the risk of loss of life of each individual;
- the global risk index, providing a measure of the total risk of loss of life in the Region.

The resulting distributions for the 2010 and 2011 funds are illustrated in Fig. 2.

3.1. Seismic Upgrading of Existing Constructions

As far as public buildings and bridges are concerned, the contribution of the State is evaluated as a quota of a conventional total cost for intervention, as follows:

a. Local strengthening:
100 € per cubic meter of the total volume of the building,
300 € per square meter of the bridge deck;

b. Seismic upgrading:
150 € per cubic meter of the total volume of the building,
450 € per square meter of the bridge deck;

c. Demolition and reconstruction:
200 € per cubic meter of the total volume of the building,
600 € per square meter of the bridge deck.

The selection of the buildings and bridges to be retrofitted is relied upon regions, that must take into account the seismic safety verification carried out according to the Ordinance 3274/2003. The contribution of the State depends on the safety deficit and therefore on the result of the safety verification, according to the following rules:

- 100% of the conventional total cost if $\alpha \leq 0.2$;
- 0% of the conventional total cost if $\alpha > 0.8$;
- [(380 - 400 α)/3] % of the conventional total cost if $0.2 < \alpha \leq 0.8$

Where α is the ratio between the PGA value producing the attainment of the ultimate limit state and the PGA value corresponding to the seismic design action.

At present, the retrofitting programs of the regions are being delivered to DPC for the 2011 funds, while for the 2010 funds 77 buildings are being retrofitted with an average contribution of about € 410,000 each.

As far as private buildings are concerned, the same types of intervention are allowed. However the State contribution must be considered as an incentive rather than a total refund of the expenses, being aimed at partially refunding the costs of the intervention on the structural parts only. Refundable costs are as follows:

a. Local strengthening:
€ 100 per square meter of the total surface area of the building, with a maximum of € 20,000 per dwelling unit and € 10,000 per unit with different use;

b. Seismic upgrading:
€ 150 per square meter of the total surface area of the building, with a maximum of € 30,000 per dwelling unit and € 15,000 per unit with different use;

c. Demolition and reconstruction:
   € 200 per square meter of the total surface area of the building, with a maximum of € 40,000 per dwelling unit and € 20,000 per unit with different use.

Further incentives are provided by the State, with recent laws, allowing for tax deduction of up to 50% in ten years on the costs that are not covered by the State contribution.

The selection of the private buildings to be retrofitted with the State contribution is quite critical, both because of the huge number of private buildings needing seismic retrofit and because the general lack of any seismic vulnerability or risk assessment, useful to decide individual priorities.

A first criterion is related to the number of municipality on which this action can be applied. This decision is relied upon Regions, that can adopt different criterion - e.g. priority given to municipalities with the highest seismic hazard in the Region.

A second criterion is related to the rules to give a priority classification of individual buildings. This criterion must be necessarily simple to apply, as in principle it should not need a specific expertise. It is therefore based on quite rough information, not needing a professional consultancy, such as the age of the building, the type of structure, the human lives exposure, the seismic hazard of the site.

Table 1. Scores for the evaluation of the priorities of private buildings.

Age	Reinforced Concrete Structure	Masonry or Mixed Structure	Steel Structure
Before 1919	100	100	90
Between 1920 and 1945	80	90	80
Between 1946 and 1961	60	70	60
Between 1962 ed il 1971	50	60	40
Between 1972 ed il 1981	30	40	20
Between 1982 ed il 1984	20	30	10
After 1984	0	0	0
After 1984 with unfavorable reclassification	10	15	5

According to the age and the type of structure, the score reported in table 1 are assigned to the building under consideration. The assigned score is then increased by 20% in case of buildings designed with no seismic criteria, according to the year of seismic classification of the municipality, thus obtaining a score related to the vulnerability of the building. The vulnerability score is then modified, by a factor "F", to express a total risk score, considering the human exposure, through the average daily number of inhabitants, and the design peak ground acceleration on stiff soil, deduced from the 475 yrs return period hazard map (Fig. 1). In order to optimize the investment in terms of risk reduction, in the expression of the factor F there is also the requested contribution at the denominator, so that the final score expresses the quota of risk which is counteracted by each Euro of State investment:

$F = K \cdot (a_g/g) \cdot (\text{No. inhabitants}) / (\text{contribution in €}) \quad \leq 100$

Where K is a normalizing constant taken equal to 200,000. A further increase of 50% is allowed in case of adjacency to routes which are strategic in the civil protection plan, according to an integrated approach to the seismic risk mitigation.

A web tool that permits to easily calculate the score of a given building is put at disposal of citizens, so that they can easily make their evaluation to decide whether presenting their request and for which kind of intervention - local strengthening, upgrading, reconstruction - to apply.

A specific remark is deserved by the introduction of the type of intervention named "local strengthening" for both public constructions and private buildings, as an alternative to global upgrading interventions. Local interventions are expressly considered by the new Italian technical standards (Minister of Infrastructures, 2008), in order to strengthen single structural elements or portions of a structure, without varying the global structural behavior. In the seismic case they can be aimed at reducing or eliminating those unfavorable behaviors of single elements or structural parts that, due to inadequate local strength and/or ductility, can produce anticipated brittle failures. This is typically the case of external beam-column joints of reinforced concrete framed structures or of the connections of orthogonal walls and walls with slabs in masonry buildings.

According to the code, local strengthening does not require a global analysis of the structure, given the assumption that the seismic behavior of the construction is not substantially changed but only its resistance improved. What has to be evaluated is only the increase of the strength and/or ductility of the local failure mechanism, thus speeding up considerably the time needed for design, and then the advancement of the vulnerability reduction program. Once made, local strengthening interventions allow a structure to attain its potential global strength and ductility capacity - avoiding local fragile mechanisms - and, then, to considerably rise its global seismic safety.

Obviously there must be some conditions on the characteristics of the existing structure and on the kind of intervention, in order local strengthening to be effective and not producing unpredicted unfavorable global behavior. Moreover, the structural parts not subjected to strengthening should be able to sustain the strength and ductility demand redistributed by the increase of local capacities.

Local strengthening was widely used after the 6 April 2009 Abruzzo Earthquake, for the rapid rehabilitation of 35 school buildings (Di Ludovico et al. 2009) to permit a regular restart of the scholar year in September, less than six months after the mainshock (see Fig. 3). As mentioned in a previous paragraph, it was then allowed for the State contribution as the rehabilitation measure for private buildings with usability grade B or C - i.e. not severely damaged - thus allowing them to attain not only their complete repair, but also a considerable increase of their safety. In order to facilitate the designer's work, guidelines were drafted in the aftermath of the Abruzzo earthquake (Dolce, Manfredi, 2011) and put on the web (www.reluis.it).

An ex-post analysis of the global safety of the "locally strengthened" r.c. school buildings showed that almost the full seismic upgrading can be reached (Frascadore, 2011) with local strengthening. Similar positive results have been found for some examined cases of dwelling masonry buildings, of which two examples are shown in Fig. 4. It can be seen that the seismic resistance against the out-of-plane collapse of supporting walls in masonry buildings can be increased by one order of magnitude, by just putting effective ties at the floor levels.

More recently, after the 20-29 May 2012 Emilia Earthquakes, the local strengthening concept was also adopted for the first countermeasures against the dangerous collapses of prefabricated industrial buildings designed with no seismic provisions, as stated in the Law by Decree n. 74 (see Fig. 5).

Figure 3. Local strengthening of a reinforced concrete school building in L'Aquila based on carbon fiber

wrapping for strength and ductility improvement of external beam-column joints.

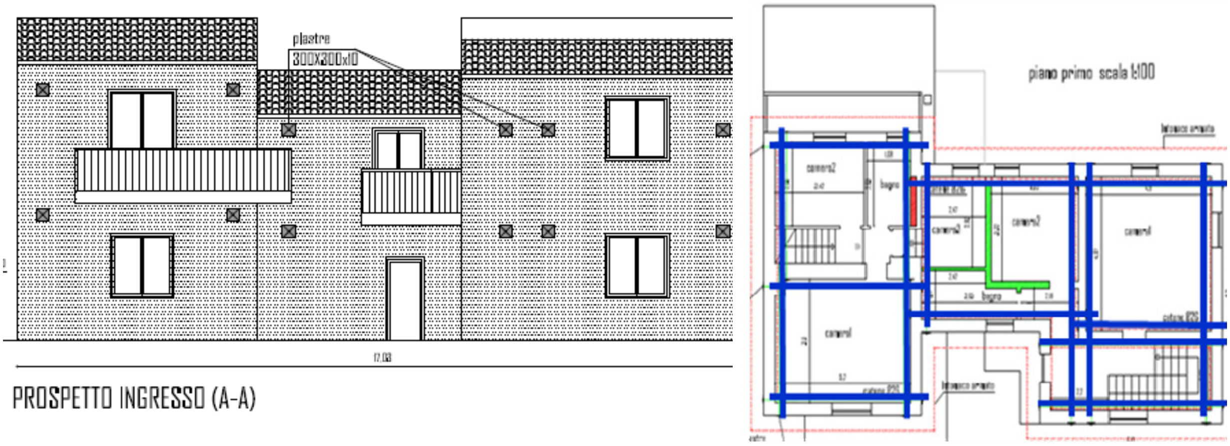


Figure 4. Local strengthening of a masonry building using steel ties to increase the ultimate limit state pga from 0.03g to 0.49g related to out-of-plane collapse of walls, for a total cost of 100 €/sqm.

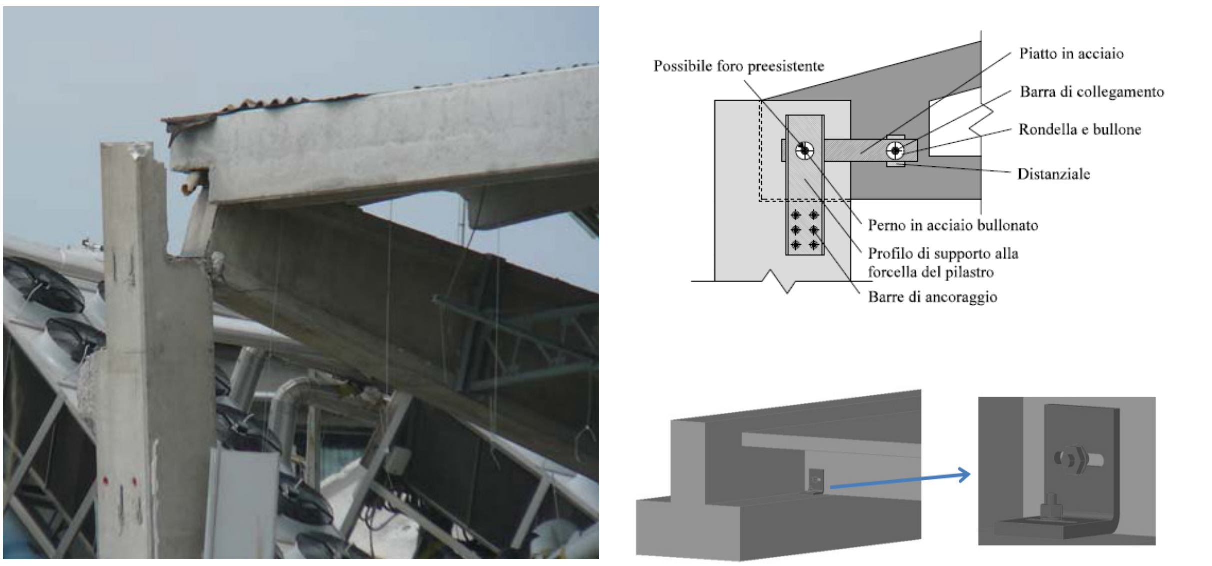


Figure 5. Typical collapse mechanism of prefabricated industrial buildings and possible local strengthening interventions according to guidelines (Gruppo di lavoro, 2012, www.reluis.it).

The Ordinances 3907 and 4007 define the categories of local strengthening intervention through the goals that must be attained, as follows:

a) increasing the ductility and/or the strength in compression and shear of columns, beams and joints of reinforced concrete structures;
b) reducing the risk of out-of-plane collapse of walls or of their portions in masonry structures, eliminating arch or vaults thrusting forces or increasing the ductility of masonry elements;
c) secure non structural elements, such as infilled panels, cantilevers, chimneys, cornices and other heavy elements, dangerous in case of fall.

The conditions that must be fulfilled by existing buildings under which local strengthening interventions are allowed for masonry buildings are:

- No more than three stories above the ground,

- No supporting walls not built on the foundation,
- No supporting walls made of non structural bricks,
- No medium-heavy structural damage,
- No stone masonry walls with disorderly texture,
- Compressive stress in the supporting walls less than 1/5 of the average compressive strength,
- Good preservation of the building.

For reinforced concrete and for steel structure buildings the conditions are:

- Date of construction later than 1970,
- Structural system made of lateral force resisting substructures along both orthogonal horizontal directions,
- No more than four stories above the ground,
- Relatively compact layout,
- No medium-heavy structural damage,
- Compressive stress in the vertical reinforced concrete structural elements, due to the only permanent and variable loads, less than 4 MPa,
- Compressive stress in the steel elements less than 1/3 of the yielding stress and slenderness of columns less than 100,
- Compressive stress in the vertical structural elements due to permanent and variable loads less than 4 MPa,
- Good preservation of the building.

In case one apply for global upgrading intervention, for which the analysis and safety verification of the entire structure is required, a minimum value of the capacity/demand ratio equal to 60% of the full safety or, at least, an increase of 20% shall be reached.

A further measure of the two Ordinances 3907 and 4007 is devoted, as above said (letter d), to other urgent interventions for the seismic risk mitigation, with particular reference to situations of high vulnerability and exposure, to assure the best implementation of civil protection plans. Although no specific category of construction is indicated in the Ordinance, it appeared important to draw the attention to important components of the civil protection plans, such as bridges in the main escape and communication transport routes, inside or leading to urban settlements. In this case vulnerable bridges and viaduct are considered. The measure is regulated by a Decree of the Chief of the Department. The contribution, whose amount is given according to the rules previously described, can be assigned to bridges and viaducts which are part of transportation infrastructures, or which interfere with them, that serve escape routes identified by the municipality emergency plan. The measure is limited to the sites where a_g is not less than 0.2 g, which becomes 0.15 g in areas subjected also to volcanic risk.

3.2. Seismic Microzonation

Seismic microzonation is identified as one of the key tool in the national plan for seismic prevention, for a strategy of seismic risk mitigation in the single municipalities.

With the first two ordinances, relevant to the funds for 2010 and 2011, two principles are assessed aimed at giving operational capability and concreteness to the financed seismic microzonation program:

1) The microzonation studies must be incorporated in the urban planning of municipalities and common methods and standards must be adopted at national level;
2) The interventions on the territory aimed at the seismic risk mitigation must be coordinated among them, starting from the verification of the efficiency of the systems for emergency management.

In order to implement this mandate, an inter-institutional technical commission for the coordination of the microzonation studies has been established. It prepares technical documents, provides addresses for and monitors the activities and the state of implementation over all the national territory.

Seismic microzonation (SM) is a multidisciplinary study. It requires, at all levels of detail, the collection, archiving, processing and representation of a considerable amount of data, of different nature and significance, which are needed to describe the integrated model of the subsoil. It is therefore evident the exigency of collecting all the necessary pieces of information in a rational and well organized manner, in order to make them of immediate exploitation for the SM studies. The realization of such an archiving, management and representation system requires the development of clear and shared procedures and complex problems to be overcome, relevant not only to the data storing modalities, but also to their selection, homogenization, codification and cartographic representation.

The technical reference document is the already described "Guiding principles and Criteria for Seismic Microzonation" (ICMS08, MS Working Group, 2008). Its fulfillment is compulsory for the execution of SM studies in the national territory. Standards for archiving and cartographic representation are employed, consistently with ICMS08 criteria. They have been further improved, based on the observations of the experts of research institutes, universities, Regions and the Commission itself, coming from the experience in the SM of the L'Aquila area and other experiences meanwhile made. Summarizing, the problems dealt with are essentially the following three:

- Defining the standards for the data collection (archiving standards),
- Building an archiving system, as well as the inquiry and the processing of the same data,
- Defining the standards for the cartographic representation.

The products for which informatics and graphic representation standards have been defined are:

- Map of investigations,
- Geological-geotechnical map,
- Map of the homogeneous microzones in a seismic perspective (level 1),
- Map of the seismic microzonation (level 2 and level 3).

The specific objectives of the standards are:

- Elaborating representations which simplify and summarize significant elements and themes,
- Homogenizing representations by different subjects, to make it easier to read and compare the results relevant to different areas,
- Guaranteeing as a simple and flexible archiving system as possible.

Table 2. State contributions for the execution of microzonation studies in the years 2010 and 2011.

Population	Contribution 2010 (Ord. 3907)	Contribution 2011 (Ord. 4007)
Inhabitants ≤ 2,500	6,000 €	7,200 €
2,500 < inh. ≤ 5,000	8,000 €	9,600 €
5,000 < inh. ≤ 10,000	10,000 €	12,000 €
10,000 < inh. ≤ 25,000	12,000 €	14,400 €
25,000 < inh. ≤ 50,000	14,000 €	16,800 €
50,000 < inh. ≤ 100,000	16,000 €	19,200 €
100,000 < inh.	18,000 €	21,600 €

The State contribution provided to the single municipality, as a function of the number of inhabitants, to carry out seismic microzonation studies has been quoted differently for the years 2010 and 2011, as shown in table 2. For the year 2010 (Ordinance 3907) local administration had to cofinance the activities in a measure of at least 50% of the total cost. For the year 2011 the State contribution is increased by 20%, while local administrations have to cofinance for at least 40% of the total cost.

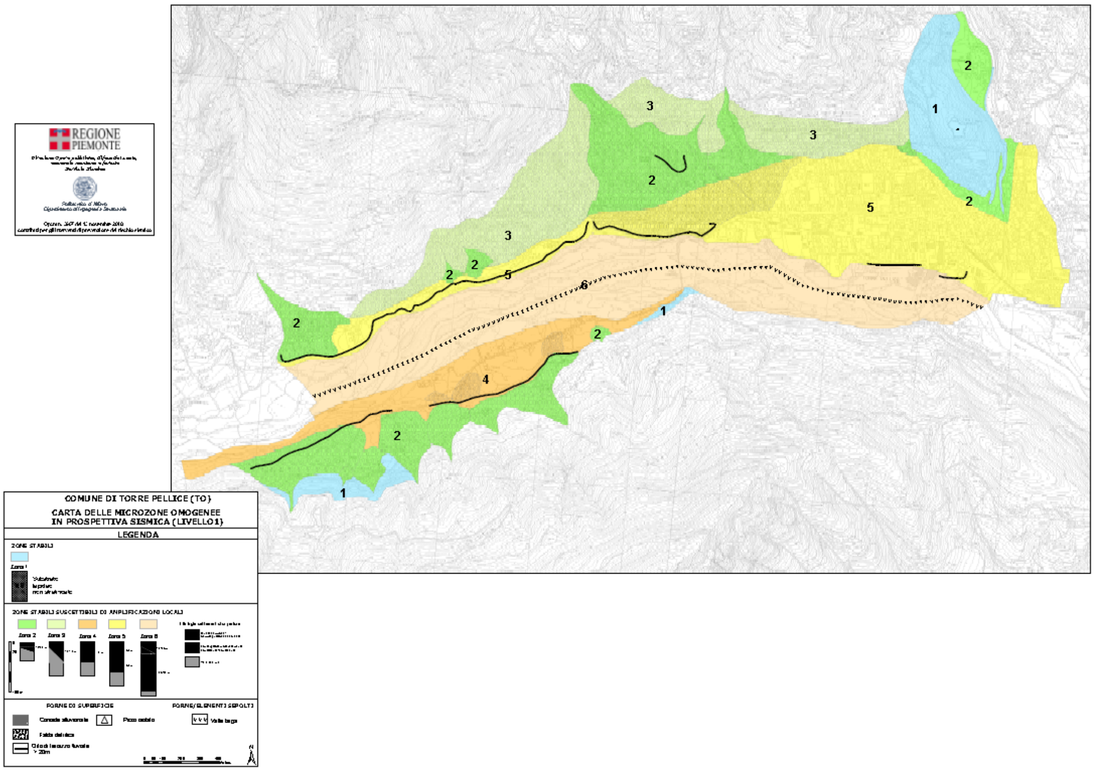


Figure 6. Example of microzonation map at level 1 obtained with the year 2010 funds.

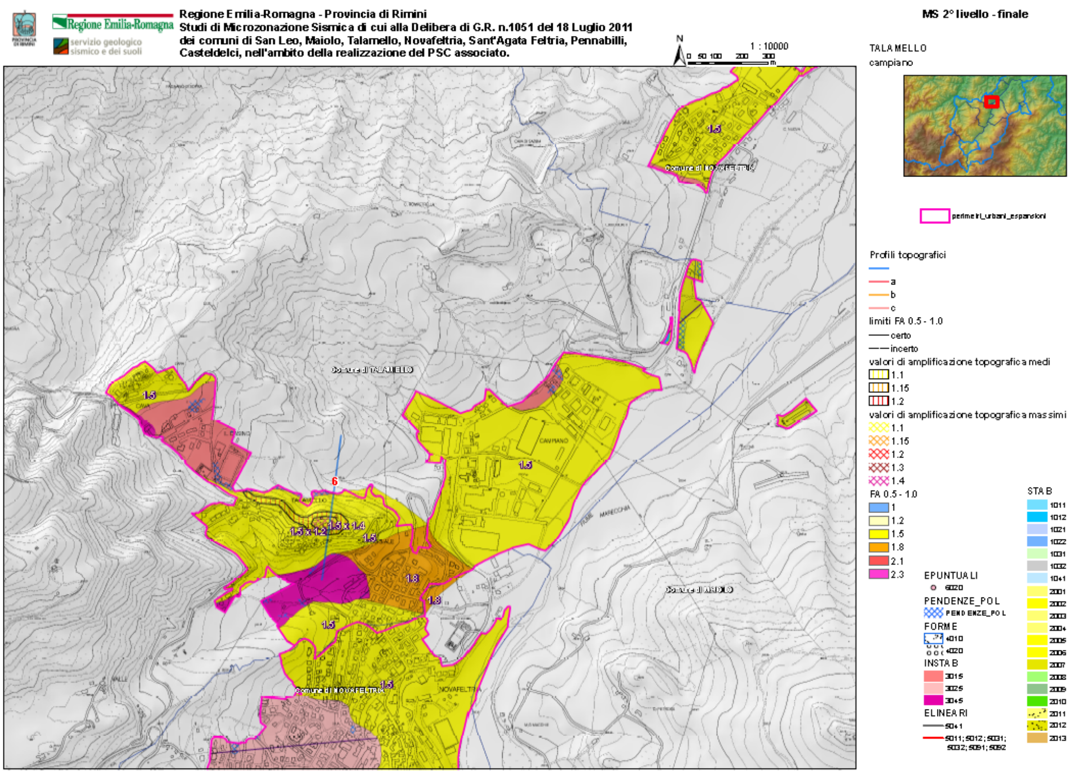


Figure 7. Example of microzonation map at level 2 obtained with the year 2010 funds.

Moreover, incentives, such as the doubling of the State contribution, are given to favor the implementation of level 3 microzonation if some conditions are fulfilled, related to the previous execution of level 1 and the inadequacy of level 2 microzonation with respect to the actual geological situation. The analysis of the Limit Condition for the Emergency, as described in the following paragraph, becomes compulsory in this case.

Also to be mentioned is the strict time scheduling, for which the microzonation studies must be completed in less than one year and delivered to the Commission for the final check.

A couple of examples of maps relevant to studies at levels 1 and 2 respectively are shown in Figs. 6 and 7.

At the current state of advancement, all the regions, except one, have almost completed their microzonation studies financed with the 2010 funds, relevant to 432 municipalities. 78 studies, out of 432, are carried out at the level 2 or 3 of ICMS08. The average contribution for each study results to be of the order of € 9,000 per municipality. The total number of inhabitants of the municipalities interested by the microzonation studies is 4,300,000, so that the State contribution per inhabitant is about € 0.9. Obviously the actual total costs of the studies are at least the double of the figures given above.

3.3. Limit Condition for the Emergency

With the objective of integrating the interventions aimed at the seismic risk mitigation at the municipality scale, an activity has started for the verification of the efficiency of the emergency management systems with respect to the envisaged damaged condition of an urban settlement after a destructive scenario earthquake. At this end the so-called Limit Condition for the Emergency (LCE) has been established and a method for its analysis has been set up.

LCE is defined, among different limit conditions of an urban settlement, as the condition for which, after a seismic event, the urban settlement undergoes such physical and functional damage as to interrupt almost all its urban functions, including dwelling, while the functionality of most of the strategic functions for the emergency management are preserved, as well as their internal connection and their access routes from the external territorial context.

Such definition implies that for the analysis of a given settlement it is necessary to identify first of all:

- The structures finalized to the emergency management;
- The transport interconnection system among those structures and the accessibility from the external territory.

It is therefore necessary to identify these items, acquire the minimum pieces of information on them and analyze their vulnerability and their risk. At this end, five types of survey forms have been set up and enforced with the Decree of the Chief of DPC of 27 April 2012. They are relevant to:

1) Strategic buildings (ES), i.e. buildings essential for the emergency management, such as town hall, operational centers, hospitals, etc. Besides the hosted strategic function, the exposure data and the localization of the building, the main geometrical and structural features are reported, such as surface area, height, number of stories, type of vertical and horizontal structures; also the outcome of the microzonation at the site of the building, with related geological/geotechnical risks are reported. All these pieces of information will allow a loss of operability risk analysis to be made on the specific building.

2) Emergency areas (AE), such as meeting and shelter areas, as well as deposit areas (where materials and goods useful for the emergency management are temporarily set down); these areas, besides having consistent dimensions, shall be easily reachable even by trucks, and

must have power and water, as well as sewage, facilities easily accessible. Information requested, besides the localization and the geometry, are those coming from the microzonation study, especially for what concerns potential instability, and those relevant to hydrogeological and flooding conditions.

3) Routes for the internal connection or the access (AC) to strategic elements (ES and AE). Routes are identified as a sequence of streets connecting two strategic elements (strategic building or emergency area) or leading from outside main roads to one or more strategic elements. Obviously nodes are created at the intersection between branches. Besides the localization on a map and the geometry (length and width), as well as other data useful to define the functionality of the route, information coming from the microzonation study, especially concerning potential instability, and those relevant to hydrogeological and flooding conditions are requested. Finally the number of structural aggregates potentially interfering with the route in case of structural collapse are reported.

4) Structural aggregates (AS) along the above said routes whose collapse can interrupt them or including ES. There are required all the geometrical data of the building complex that are useful to describe the potential interferences with the routes and to describe the situations which potentially increase the vulnerability of the aggregate due to unfavorable structural interactions of the buildings that compose the aggregate - e.g.: presence of large span structures, geometrical variations of adjacent buildings and related geometrical irregularities, presence of connecting arches and vaults, presence of towers, chimneys, etc.. Further needed pieces information are those relevant to the outcome of the microzonation study at the site of the aggregate, with related geological/geotechnical dangerous situations.

5) Structural units (US) belonging to the above said aggregates. Structural units are entire buildings, from ground to roof, which can be distinguished inside a structural aggregate, for their specific features, with respect to the adjacent buildings. Besides data for the identification and localization of the structural unit in a map, pieces of information similar to those requested for strategic buildings must be reported in the form, with the aim of mainly evaluating the risk of collapse and, then, of interruption of the route with which the structural unit can potentially interfere.

The procedure for the LCE is as follows:

i. The strategic functions are identified and the relevant strategic elements are localized in the technical map, on the basis of the civil protection plan of the municipality;
ii. The interconnection routes between strategic elements are identified, possibly from the existing planning documents, keeping them to the minimum needed number, but also considering possible redundancy;
iii. The accessibility routes to reach the ensemble of the strategic elements from outside are identified, possibly from the existing emergency planning documents;
iv. Structural aggregates and isolated buildings that can interfere with the connection or accessibility routes or with the emergency areas are identified and reported on the map. Interference potential is assigned to an aggregate in relation to its height and the width of the street or the distance from the emergency area;
v. One or more teams of at least two surveyors fill the forms, partly in the field and partly on the desk, according to the type of information;
vi. All the content of the forms is computerized, using a software purposely implemented, and put on a GIS; the data storage structure also guarantees the link with the cartographic data base.

Besides the survey forms, the cartographic support is fundamental for the LCE analysis. There are represented the main characteristics and their relationships in the specific settlement under consideration, then identifying the main factors of criticality that can affect the performances of the system. All the collected pieces of information will constitute the minimal knowledge base to make evaluations in terms of efficiency of the existing emergency system and of possible improvements.

In order to quantify the performances of the system, a probabilistic approach has been set up, so that the probability of failure of the single components and of the sub systems can be evaluated, starting from the data collected through the survey forms and its cartographic representation, taking into account the local hazard features obtained from the microzonation studies (see Figs. 8 and 9). A probabilistic operational efficiency index can then be assessed for:

- single strategic buildings, single emergency areas, single branches of the fundamental interconnection and access routes;
- subsets of strategic elements (strategic buildings and/or emergency areas), set of the interconnection routes and/or the access routes;
- single strategic elements including its access routes;
- overall LCE system.

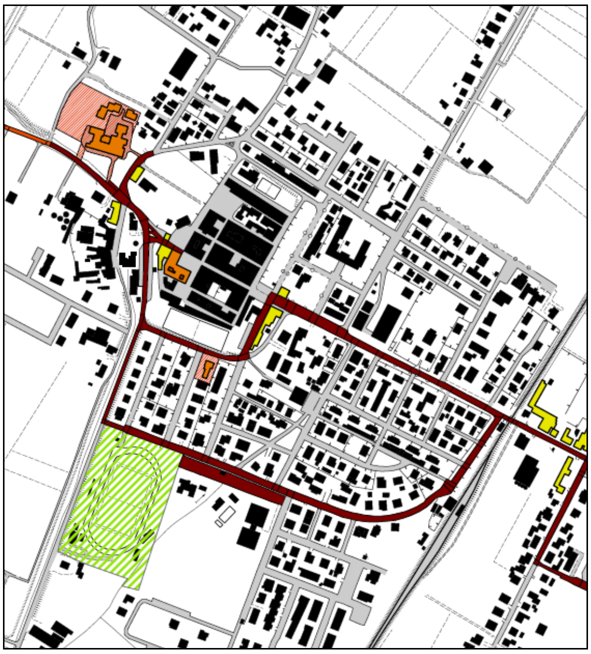


Figure 8. Map for the execution of LCE Analysis, where main routes and strategic elements are identified.

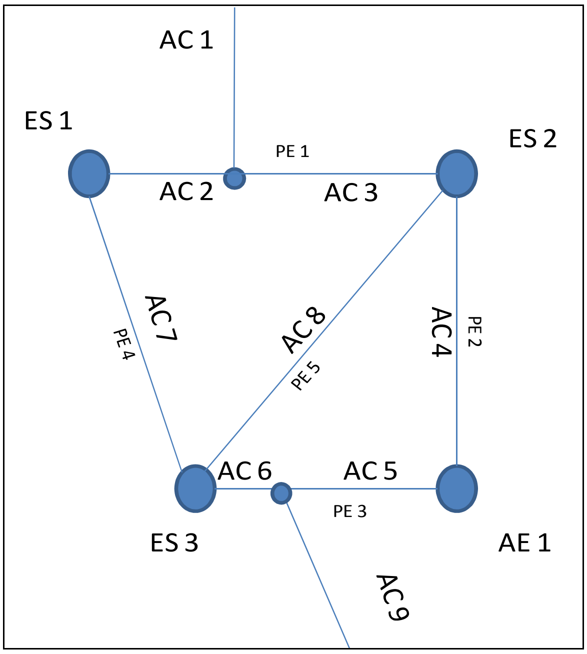


Figure 9. Scheme for the evaluation of the probabilistic operational efficiency indices.

The evaluation of the efficiency of the emergency management system will be based on the comparison between the current state and the performances required to the system as a whole, through evaluations referred to single elements and subsets. The evaluation of the distance between the surveyed and the target conditions, as envisaged by the Civil protection plan, represents the final objective of the analysis. Improvements of the emergency plans can then be easily identified, and implemented with immediate effects – e.g. by changing the location of the strategic function, by rethinking the system of routes of interconnection and external access - or with long term effects – e.g. by establishing priorities for funding retrofit interventions on strategic buildings or structural aggregates interfering with the routes - or even through the governing tools of the territory - e.g. adopting specific norms and indications on the land use and the admissible transformations.

The analysis of LCE has been introduced for the first time in the Ordinance 4007, relevant to the 2011 funds, as a voluntary application, with some incentives, connected to the microzonation studies. as said above. However some pilot applications have already been made on small and medium size settlements, in order to test the feasibility and the effectiveness of the procedure, with very satisfactory outcomes, concerning both the feasibility and the usefulness of LCE analysis for emergency planning.

4. CONCLUSION

The actions for the mitigation of seismic risk can be classified according to three lines of actions, i.e. the improvement of the knowledge, the reduction of the vulnerability and exposure, the mitigation of the effects. Very often these lines, and even the single actions, are separately considered and the relevant objectives almost independently pursued, being in charge of different organisations.

It is well recognised that the main action should be the generalized reduction of the seismic vulnerability, and then of the risk of collapse, of existing constructions, as well as the realization of new constructions with adequate seismic safety. Thus doing, the risk of collapse for the reference "design earthquake" would reduce to almost zero and consequently the human losses, while the socio-economic losses becomes acceptable allowing for a rapid recovery. Unfortunately this objective is the lengthiest and by far the most expensive of the objectives to be attained: a huge investment and a very long term risk mitigation policy would be required. Therefore the progressive implementation of the vulnerability reduction of constructions must be accompanied by other measures that can be implemented in a short time, requiring lesser - by some orders of magnitude - investments. They must be aimed at rationalizing, optimizing and accelerating the interventions. In other words if the final and ideal objective (perhaps a utopia in a country with such a highly vulnerable built environment like Italy) is reaching adequate safety of all the public and private constructions, intermediate objective should be pursued and attained in a reasonable time windows and a multifaceted action for seismic risk mitigation should be implemented.

The mitigation actions implemented since the eighties in Italy are described in this paper. Apart from the really small and somewhat episodic investments made, the main comment on the actions put into practice until 2003 is that the different actions were applied separately, with neither temporal nor spatial continuity in the implementation of the various actions and sometimes little finalization.

In other words it appears quite clear that there was a lack of a general strategy, according to the generalized lack of awareness of the risk and then of a policy for risk reduction.

As explained in the paper, things changed considerably in 2003, after the S.Giuliano Earthquake, when different, in some way coordinated, actions were initiated and more important, although largely insufficient, investments were made in the following two years.

Unfortunately this impulse lasted few years, and it was practically exhausted when a new more destructive earthquake occurred on 6 April 2009 in Abruzzo. Again, like after every destructive earthquakes, the attention of politicians raised up and a fund was immediately allocated for a seven years seismic prevention program.

No need to say that the fund allocation is largely insufficient and that a purely retrofitting program realized at the rate determined by that annual fund availability would require some centuries to achieve the objective of securing all the vulnerable constructions. Meanwhile hundreds of billions of Euro would be spent for repairing and rebuilding after destructive earthquakes. It is then necessary to develop different actions, essentially along the main line of the reduction of the vulnerability and exposure, according to an integrated program that should rationalize and optimize, as well as multiply the effects, of the investments.

The National Plan for Seismic Risk Prevention set up in 2010 described in this paper aims at realising such integrated strategy. Its qualifying aspects can be summarized as follows:

- It is a medium term program with a seven year perspective and a clear objective: reducing expected human losses;

- The program is flexible, since every year the different actions and the relevant investments are decided and funded, according to the practical implementations of the measures in the previous years and the scientific advancements that can improve effectiveness;
- Seismic microzonation studies are cofinanced and promoted and can be carried out according to different levels of accuracy, but following well defined guidelines, with uniform standards and a well defined progression from lower to higher levels;
- Seismic microzonation (SM) is integrated into urban and emergency planning activities;
- The analysis of the limit condition for emergency of urban settlements (LCE) is introduced as a tool for improving the seismic emergency system, but also for increasing the awareness of public administrators and better defining a risk reduction strategy at local level, as well as establishing priorities for future retrofit interventions;
- Regions are constantly supported for the SM studies and LCE analyses, in order to fulfill general standards and requirements, by a commission with large participation of experts.
- Retrofit of private buildings, besides public constructions, is funded, in order to decrease the vulnerability of the private building stock, but also to increase the awareness of risk of private owners;
- Retrofit of public buildings are funded consistently with the safety verifications activated by the post S.Giuliano Earthquake provisions (Ordinance 3274/2003), thus guaranteeing the continuity of action with respect to the prevention activities initiated in the past;
- The maximum flexibility is allowed for the type of retrofit intervention to adopt for public buildings and bridges and for private buildings: from local strengthening up to demolition and reconstruction;
- Retrofit of bridges and viaducts important for emergency planning are promoted and financed with a dedicated fund;
- Full integration of seismic microzonation, limit condition for emergency analyses and retrofit interventions will be achieved in a near future as soon as the relevant studies are completed, so that retrofit priorities can be decided according to seismic vulnerability, local hazard and emergency planning exigencies.

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REFERENCES

Borzi, B., Ceresa, P., Faravelli, M., Fiorini, E., Onida, M. (2011). Applicazione del metodo meccanico SP-BELA alla definizione di rischio sismico e scenari di danno del patrimonio edilizio italiano, *14th Italian Conference of Earthquake Engineering*, Bari, Italia

Bozzoni, F., Lai, C.G. (2012). Seismic risk assessment of Italian seaports using GIS technology: the ports of the Calabria Region. 15 WCEE. Lisbon.

Cherubini, A., Corazza, L., Di Pasquale, G., Dolce, M., Martinelli, A., Petrini, V. (1999). Censimento di vulnerabilità degli edifici pubblici, strategici e speciali nelle regioni Abruzzo, Basilicata, Calabria, Campania, Molise, Puglia e Sicilia – Cap. 4: Risultati del Progetto. Dipartimento della Protezione Civile, Roma.

Di Ludovico, M., Di Pasquale, G., Dolce, M., Manfredi, G., Moroni, C., Prota, A. (2009). Behavior of scholastic buildings after L'Aquila earthquake. *Progettazione Sismica*, **3**.

Di Pasquale, G., Dolce, M., Severino, M. (2007). Analisi comparata dei modelli per la ricostruzione post-terremoto: l'evoluzione della normativa dal terremoto del Belice (1968) a quello del Molise (2002). *Dall'emergenza alla ricostruzione* (F. Barberi editor), 29-54, Regione Umbria, Quattroemme editore, Perugia.

Dolce, M., Galanti, E., De Sortis, A., Di Pasquale, G., Goretti, A., Ferlito, R., Papa, F., Papa, S., Pizza, A. G., Sergio, S., Severino, M. (2007b). Iniziative nazionali per la valutazione e riduzione del rischio sismico. *12th Italian Conference of Earthquake Engineering*, Pisa.

Dolce, M. (2008). Civil Protection vs. Earthquake Engineering and Seismological Research. *14th WCEE,*

October 2008, Beijing, China. Keynote lecture.
Dolce, M. (2009a). Seismic Risk Mitigation in the Aftermath of the Abruzzo Earthquake. *Istanbul International Conference on Seismic Risk Mitigation*. Istanbul. Invited lecture.
Dolce M. (2009b). Mitigation of Seismic Risk in Italy Following the 2002 S.Giuliano Earthquake. *WCCE-ECCE-TCCE Joint Conference Earthquake & Tsunami*. Istanbul. Keynote lecture.
Dolce, M., Di Pasquale, G., Albanese, V., Benetti, D., Bramerini, F., Coppari, S., Corina, A., De Rosa, G., De Sortis, A., Emili, P., Ferlito, R., Filippi, L., Giordano, F., Goretti, A., Lo Presti, T., Lucantoni, A., Mercuri, M., Moroni, C., Orlandi, N., Paoli, G., Papa, F., Pizza, A., Procida, F., Rinaldelli, M., Sergio, S., Severino, M., Speranza, E., Veschi, A., Zambonelli, E., Manfredi, G., Di Ludovico, M., Palermo, G., Prota, A., Verderame, G., Corazza, L., Cifani, G., Mannella, A., Martinelli, A. (2009c). Quick surveys: post-earthquake usability inspections. *Progettazione Sismica*, **3**.
Dolce, M., Naso, G. (2009). La microzonazione sismica per la ricostruzione nell'area aquilana: risultati preliminari. *Progettazione Sismica*, **3**.
Dolce, M., Manfredi, G. (editors). (2011). Linee Guida per la riparazione e rafforzamento di elementi strutturali, tamponature e partizioni. ISBN 978-88-89972-29-8. Doppiavoce editore.
Frascadore, R. (2011). Influenza dei meccanismi fragili sulla sicurezza sismica di edifici esistenti in c.a. *PhD thesis, University of Naples Federico II*.
Goretti, A., Bramerini, F., Di Pasquale, G., Dolce, M., Lagomarsino, S., Parodi, S., Iervolino, I., Verderame, G.M., Bernardini, A., Penna, A., Rota, M., Masi, A., Vona, M. (2008). "The Italian contribution to the USGS PAGER Project", *Proc. of 14th World Conference on Earthquake Engineering*, Beijing.
Gruppo di Lavoro Agibilità Sismica dei Capannoni Industriali. (2012). Linee di indirizzo per interventi locali e globali su edifici industriali monopiano non progettati con criteri antisismici. www.reluis.it
Liberatore, D. (2009). Definition and Development of Databases for Risk Evaluation, Emergency Planning and Management. *The state of Earthquake Engineering Research in Italy: the ReLUIS-DPC 2005-2008 Project*. © 2009 Doppiavoce, Napoli, Italy
Manfredi, G., Dolce, M. (eds). (2009). The state of Earthquake Engineering Research in Italy: the ReLUIS-DPC 2005-2008 Project. © 2009 Doppiavoce, Napoli, Italy.
Minister of Infrastructures. (2008). Decree 14 January 2008, Approval of the New Technical Norms for Constructions (in Italian). G.U.R.I. n. 29 of 4-2-2008 – S.O. n.30
MS Working Group. (2008). Indirizzi e Criteri per la Microzonazione Sismica, 3 vol. e DVD, Presidenza del Consiglio dei Ministri – Dipartimento della Protezione Civile e Conferenza delle Regioni, Roma
Zuccaro G. (Editor). (2004). Inventario e vulnerabilità del patrimonio edilizio residenziale del territorio nazionale, mappe di rischio e perdite socio – economiche. Napoli.