SEISMIC RISK MITIGATION STRATEGIES AND PREVENTION IN URBAN PLANNING

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Abstract

Carrying out an effective seismic risk prevention strategy requires a thorough knowledge of the territory, the land and the constructions built in the area, information that is indispensable in order to analyse limit conditions in urban risk prevention planning. To this end, regulatory and technical-operative initiatives, aimed at seismic risk prevention and an improved framework of knowledge regarding the dangers and vulnerabilities of the regional territory, are highly needed.

This article illustrates the tools used for the mitigation of seismic risk associated with the analysis of the urban risk prevention planning limit conditions – construction, with the development of specific analyses and methodologies suitable for the support of seismic risk reduction interventions, aimed at the proper planning and territorial management of the interventions needed to prevent and contain possible damages.

Key words: *seismic risk management, emergency planning, seismic micro-zonation*

1. INTRODUCTION

With this kind of phenomenon, the risk derives from the size of the earthquake, the concentration of the population, the distribution of the inhabited centres, and the quality of the constructions. Seismic risk can, therefore, be substantial also in low seismic areas, due to a strong concentration of productive activities, cultural and artistic assets, inhabited centres and the presence of highly vulnerable buildings.

Risk mitigation strategies are achievable already in the urban planning phase and, above all, in the design and construction phase.

Seismic micro-zonation studies of the territory steer the urban planning choices towards the least vulnerable areas. The application of the anti-seismic criteria in the design and construction of buildings, foreseen by the technical standards, makes it possible to carry out works that can withstand seismic activities and their potential local effects.

A seismic risk is not predictable, as it is not characterised by any precursory phenomena that can determine when and where the next event will take place. Nevertheless, considering regional seismicity, seismic risk can be significantly reduced with actions of prevention.

For civil protection purposes, pursuant to Law no. 100 of July 12, 2012, forecasting activities that are aimed at studying the territory and identifying probable risk scenarios, identifying and classifying hazardous areas, and monitoring events through monitoring networks, can be carried out.

Urban planning choices compatible with the local seismic risk and the application of technical building standards, on all levels, make it possible to carry out interventions that can withstand seismic activities and their effects.

2. SEISMIC RISK: INSTRUMENTS FOR ANALYSIS AND PREVENTION

In order to mitigate the effects of an earthquake, there are well-consolidated paths to follow and they are overseen by different institutional levels on different territorial scales:

1. the legislation (national and regional);
2. the identification of the seismic risk of the territory (seismic macro-zonation and micro-zonation);
3. the territorial and urban planning (Provinces and Municipalities), followed by a proper building scale design.

The tools of seismic risk mitigation are the macro-classification of the territory, carried out on a national level, with the in-depth study of the local seismic risks through micro-zonation, entrusted to the Municipalities, while the proper anti-seismic design of the buildings reduces their vulnerability.

After 1974, in order to reduce the effects of earthquakes, the State's action focused on territorial classification (macro-classification), based on the intensity and frequency of past earthquakes and on the application of special building regulations in areas classified as seismic, establishing technical standards according to which a building must withstand the least powerful earthquakes without any serious damages and the most powerful earthquakes without collapsing, thus safeguarding, first and foremost, human lives.

In 1984, 65% of the national territory was not yet classified according to its seismic risk level.

After 2003, all the Italian Municipalities were considered as seismic and allocated in one of the four risk areas in a descending order. Eventually, the entire national territory was reclassified with respect to which earthquake standards for building construction to apply.

There are a series of environmental themed concepts and activities under the heading *seismic risk reduction,* and they are as important as they are often underestimated as to the consequences they may have with regard to the human components present.

Seismicity, that is the frequency and strength with which earthquakes occur, is a physical characteristic of the territory. Factors such as local geological configuration, population distribution and activities of production, together with building vulnerability, are what make seismic risks high, sometimes also in areas that researchers consider to be of relatively lower seismic risk.

The regulations regarding seismic risk reduction, in relation to the vulnerability of the territory, have existed for a long time, firstly in national legislation and later transposed and itemised in the regional one.

Specific analyses and appropriate methodologies aim at supporting seismic risk mitigation interventions, which are reflected in the proper planning and territorial management of the actions required to prevent and mitigate the possible damages.

The following report quantifies seismic risk:

SEISMIC RISK (SR)

$$SR = [Db \cdot Le] \cdot [V \cdot E]$$

The severity of the action is therefore determined by the following factors:

- Dangerousness (Db) = probabilistically predictable frequency and intensity of the events that will affect a territory in the future (also predicting possible earthquakes);

- Local effects (Le) = variations of dangerousness within a territory with respect to the specific area conditions (also temporary).

The severity of the consequences is given by these factors:

- Vulnerability (V) = quality of the constructions and infrastructures present in a territory in terms of resistance to a certain seismic event intensity;

- Exposure (E) = distribution and structure of the population present, of the activities of production, of the resources and infrastructures of a territory.

The implementation of methods and norms aimed at reducing seismic risk in municipal urban planning is a rather recent phenomenon. Unfortunately, it has taken a long time to place the due attention on urban transformations and the seismic safety gap accumulated over the years will be very difficult to recover from with regard to the existing buildings.

It is therefore evident that there is an absolute need to adopt binding strategies to effectively reduce seismic risks by increasing the overall levels of security, in order to contain damages to people and property, and to be prepared for an effective emergency management. Seismic micro-zonation studies and the analysis of the Emergency Limit Condition are two of said strategies.

2.1 Analysis of the emergency limit condition

An earthquake emergency management system is efficient if the urban system maintains its key strategic components also after the seismic event.

It is considered an Emergency Limit Condition of the urban settlement (ELC) when the settlement continues to maintain its most strategic functions for emergency, accessibility and connection with the territorial context operational, also after a seismic event, concurrently with physical and functional damages that lead to the interruption of almost all the urban functions present, including dwellings.

If we describe the set of urban functions as a curve, as the intensity of the earthquake increases so does the level of damage. The first function to suffer a disruption would most probably be the dwelling; If the intensity increases, all the other functions will also progressively be disrupted.

The Emergency Limit Condition represents the threshold that the settlement should not cross, as it disrupts the emergency management function (fig.1).

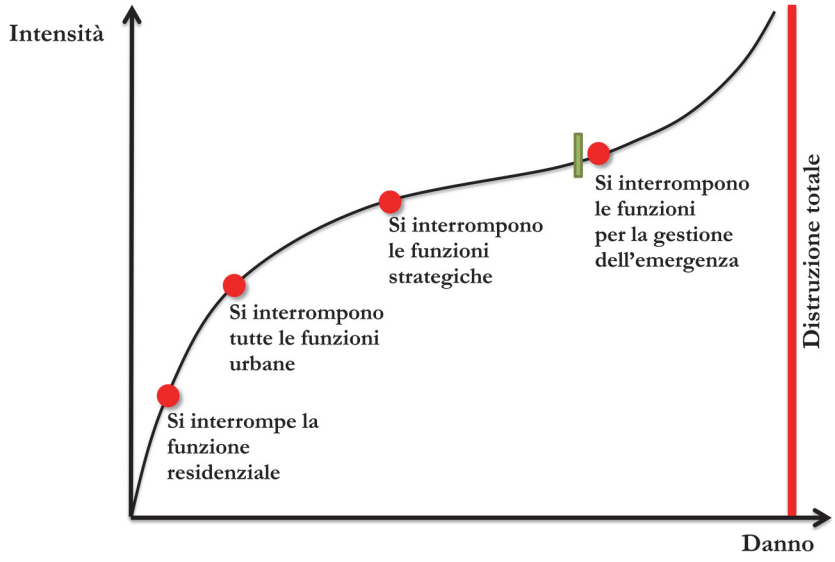


Fig. 1. Representation of the ELC

The ELC analysis of the urban settlement is developed from the data contained in the Municipal Civil Protection Plan or in the Emergency Plan in force, and it involves:

a) the identification of the buildings and areas that guarantee strategic emergency functions;

b) the identification of the infrastructures of accessibility and connection with the territorial context of the objects referred to in point (a) and any eventual critical elements;

c) the identification of structural aggregates and single structural units that may interfere with the infrastructures of accessibility and connection with the territorial context.

Therefore, the emergency condition analysis constitutes a first tool aimed at integrating local measures, in order to mitigate seismic risk on a municipal scale, and concerns the activity of verifying the emergency management system.

The analysis of the relationship of the strategic functions, which must maintain operability in relation to the territorial system (connection) and the external context (accessibility), is fundamental.

The distribution of strategic functions throughout the municipal territory and the connection with the various built areas, especially with regard to the historical centres as they represent the most vulnerable contexts, is highly important.

What is also indispensable is the analytical consideration of the buildings deemed fundamental to the management of the emergency, as they can prove to be, after a careful analysis of their structural characteristics, unsuitable because seismically inadequate.

The connections between the single elements identified, and the connections between the elements and their territorial context, must be defined by paying attention to which roads have the least building interference and by ensuring a suitable redundancy of the routes. The structural aggregates identified as interferences and the buildings that constitute them are also analysed.

The results of the analysis are also organised in a rigorous database according to a conventional filing system prepared by the Civil Protection Department.

The Emergency Condition Limit files contain the characteristics of the elements that compose it, according to the ministerial standard of representation and information storage:

- strategic buildings (SB);
- areas for emergency-shelter (EA);
- accessibility and connection infrastructures (AC);
- aggregated structures (AS) and structural units (SU).

This task, carried out with regard to the routes identified in the main inhabited centres, allows to identify the buildings that may require possible structural interventions, as it is necessary to strive for the improvement of the security conditions in order to guarantee valid connection and accessibility infrastructures, so as to provide the rescue units with constant accessibility.

The Emergency Limit Condition (ELC) includes the identification of the functions required for the emergency management system in the aftermath of an earthquake, so that urban settlements preserve the functionality of most of their strategic functions, their accessibility and their connection with the territorial context.

The detailed analysis of the Emergency Limit Condition contributes to the reformulation of the Emergency Management System of each Municipality, by correcting and/or modifying some critical elements of the system. The resulting new choices of said reformulation are then adopted in the municipal and supra-municipal emergency planning schemes.

With regard to the ELC, particular attention should be devoted to any structural interventions carried out on existing buildings and/or newly constructed works, to ensure that they do not disrupt the connection or access routes, in order to safeguard the accessibility to strategic functions in the urban

and territorial context and the route identified as a connection or access to said strategic functions in the event of a seismic emergency.

In particular, it is not coherent to carry out supra-elevations on buildings that have already been identified as disrupters by the ELC elaborations. Structural interventions must tend to reduce any disrupting conditions and, depending on the type of structural intervention, eliminate them completely.

Essentially, based on the indications of the reference documents, the following must be produced:

- The element map for the ELC analysis, on a scale of not less than 1: 15,000, containing the elements that make up the emergency management system (strategic buildings, emergency areas, accessibility and connectivity infrastructures, disrupting structural aggregates and their structural units), as well as the appropriate excerpts, on a scale of not less than 1: 2,000, containing all the areas and buildings for ELC analysis;
- The files relative to the identified elements (Strategic Buildings, Emergency Areas, Accessibility/Connection Infrastructures, Structural Aggregates and Structural Units);
- The Illustrative Report;
- The computerised database.

2.2 Seismic micro-zonation studies

Seismic Micro-zonation (SM) is a valid tool used to analyse the local seismic threat through the identification of areas of the territory that are characterised by homogeneous seismic behaviour, and to guide the choices regarding territorial and emergency planning.

Based on geological and geomorphological observations, on the interpretation of lithostratigraphic and geophysical data and, where necessary, the results of new and specific surveys, the geologist must reconstruct the three-dimensional subsurface model, with the aim of recognising, on a sufficiently large scale (municipal or supra-municipal scale), the local conditions that can significantly alter the characteristics of the expected seismic motion, or produce relevant permanent deformations to constructions and infrastructures.

Through the Seismic Micro-zonation studies (SM) it is, in fact, possible to detect and characterise the stable areas, the stable areas susceptible to local amplification and the areas subject to instabilities, such as landslides, surface breaks due to faults and dynamic soil liquefaction.

These studies represent an important learning tool, with varying costs depending on the level of detail you want to achieve:

- level 1 is an introductory step to the actual SM studies, as it consists of a collection of pre-existing data designed to subdivide the territory, in qualitative terms, into micro-zones with homogeneous seismic behaviour (Homogeneous Micro-zones in Seismic Perspective - HMSP);
- level 2 introduces the quantitative element associated with the homogeneous zones, using further and targeted surveys where necessary, defining an actual SM map;
- level 3 delivers an SM map with in-depth details of the areas that are susceptible to amplifications or unstableness, in cases of complex geological and geotechnical situations that cannot be solved with abacuses or simplified methods, or if the extension of the studied area makes it convenient to conduct a detailed global analysis or, lastly, for works of particular importance.

The field of SM study analysis generally includes areas that are constructed or under construction, thus excluding those areas where territorial or regulatory conditions do not allow, or do not envisage, settlements, infrastructures or civil protection transformations.

Seismic micro-zonation is an effective tool for the reduction of seismic risk because it allows, from the very first stages of urban planning, to assess the seismic threat of the territory, considering primarily urbanised and urbanisable areas; this allows to steer the new interventions towards less hazardous

areas and thus schedule risk mitigation interventions in areas with particular critical issues. Micro-zonation also provides useful knowledge for construction planning.

There is now a general consensus about which deposits and forms of the landscape may, during or following an earthquake, determine amplifications of seismic motion on the surface, or contribute to permanently modify the layout, causing instability by liquefaction, subsidence, landslides and fractures of the ground.

The knowledge of the areas where such effects can occur and, therefore, of the interaction between the terrain tremors and the constructions, is an essential aspect for an effective work of prevention and seismic risk reduction, especially if it is applied in the early stages of planning.

The definition of seismic hazard, significantly important for a certain and limited portion of the territory, can be considered a seismic micro-zonation, understood as the subdivision of the territory into areas characterised by homogeneous seismic behavioural resonances.

The improvement of knowledge produced by the SM studies, together with vulnerability and exposure studies, can concretely contribute to optimise the resources made available for interventions aimed at mitigating seismic risk.

The technical implementation and application procedures of MS on the Italian territory are defined by the “Indirizzi e Criteri per la Microzonazione Sismica” (Guidelines and Criteria for Seismic Micro-zonation), recently approved by the Department of Civil Protection and the Conference of Regions and Autonomous Provinces (SM Work Group, 2008).

3. TECHNICAL DOCUMENTATION OF THE GUIDELINES AND SUPPORT FOR THE SM STUDIES AND THE ELC ANALYSIS

The technical implementation and application procedures of SM and ELC analysis on the Italian territory are defined by:

- “Indirizzi e Criteri per la Microzonazione Sismica” (Guidelines and Criteria for Seismic Micro-zonation), approved by the Department of Civil Protection and the Conference of Regions and Autonomous Provinces (SM Work Group, 2008);
- Contributions for the upgrade of the "Indirizzi e criteri per la microzonazione sismica" (2008), (Guidelines and Criteria for Seismic Micro-zonation) published as an amendment to n. 2-2011 of the magazine “Ingegneria Sismica”;
- Instructions and Charts for the Emergency Limit Condition - ELC, approved with the Chief of Department Decree of April 27, 2012.

It is also worth mentioning the publication “Strategie di mitigazione del rischio sismico e pianificazione. CLE: Condizione Limite per l'Emergenza” (Seismic risk mitigation strategies and planning. ELC: Emergency Limit Condition), edited by the National Urban Planning Institute, which places the ELC in the broader context of earthquake mitigation strategies, highlighting existing relationships with seismic micro-zonation studies and territory and emergency planning.

4. NATIONAL PROGRAMME OF SEISMIC MICRO-ZONATION (SM) AND ELC ANALYSIS IMPLEMENTATION PHASE

In the Ministry of the Economy and Finance's forecasting phase, a National Seismic Prevention Risk Fund was set up annually (Figure 2), as set out by Article 11 of Law 77/2009. To this end, the following expenses were authorised:

- **M€ 44** (later reduced to 42.5) for the year 2010
- **M€ 145,1** for the year 2011
- **M€ 195,6** for each of the years 2012, 2013 and 2014
- **M€ 145,1** for the year 2015
- **M€ 44** for the year 2016

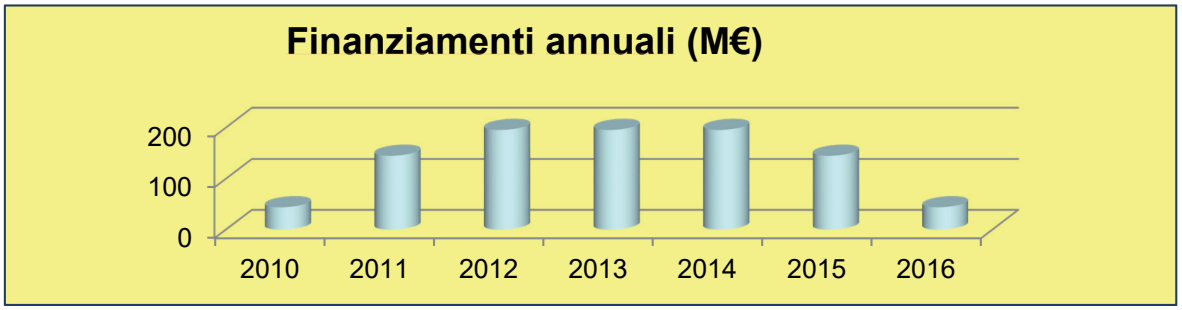


Fig. 2. Annual distribution of national funds set up for seismic risk prevention

A national technical commission, which also has the task of evaluating the studies performed, has been set up in order to support and monitor SM studies.

To get an idea of the programme implementation phase, here is some data on the state of adhesion to the regional programme of the year 2011 (Fig. 3) and the submission of SM studies on a national level of the year 2013 (Fig. 4).

Regione	Studi MS	Analisi CLE
Abruzzo	75	75
Basilicata	39	39
Calabria	118	118
Campania		
Emilia Romagna	78	15
Friuli Venezia Giulia		
Lazio	41	16
Liguria	6	6
Lombardia		
Marche	28	11
Molise	20	20
Piemonte	6	6
Puglia		
Sicilia		
Toscana	31	31
Umbria	32	32
Veneto	27	27
TOTALE	**501**	**396**

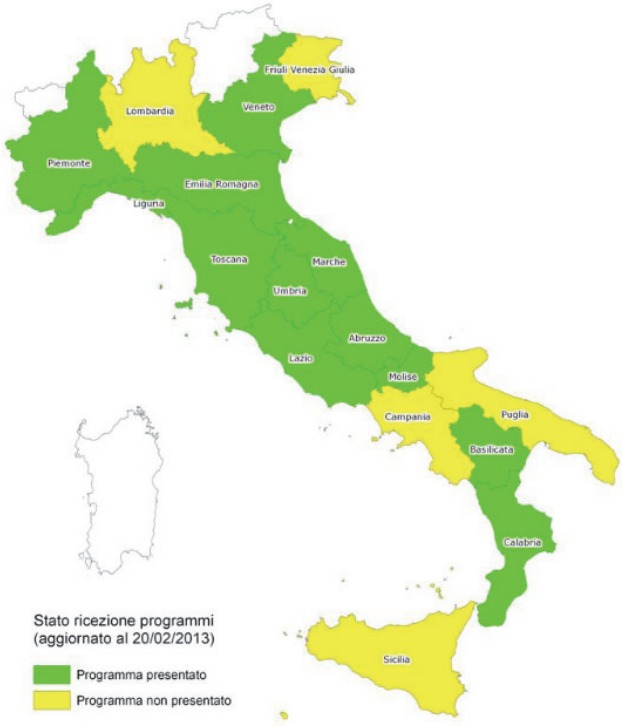
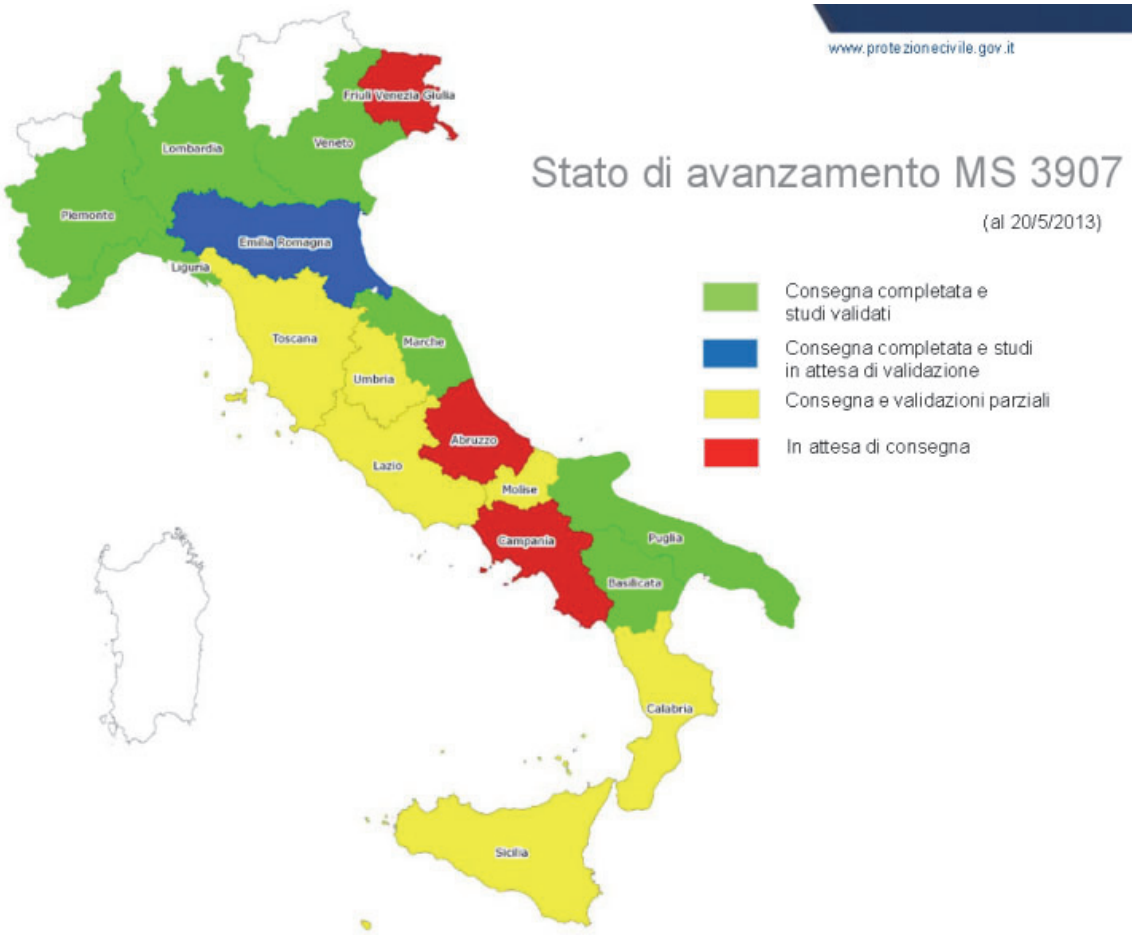


Fig. 3. Monitoring: the adhesion of the Regions in the year 2011



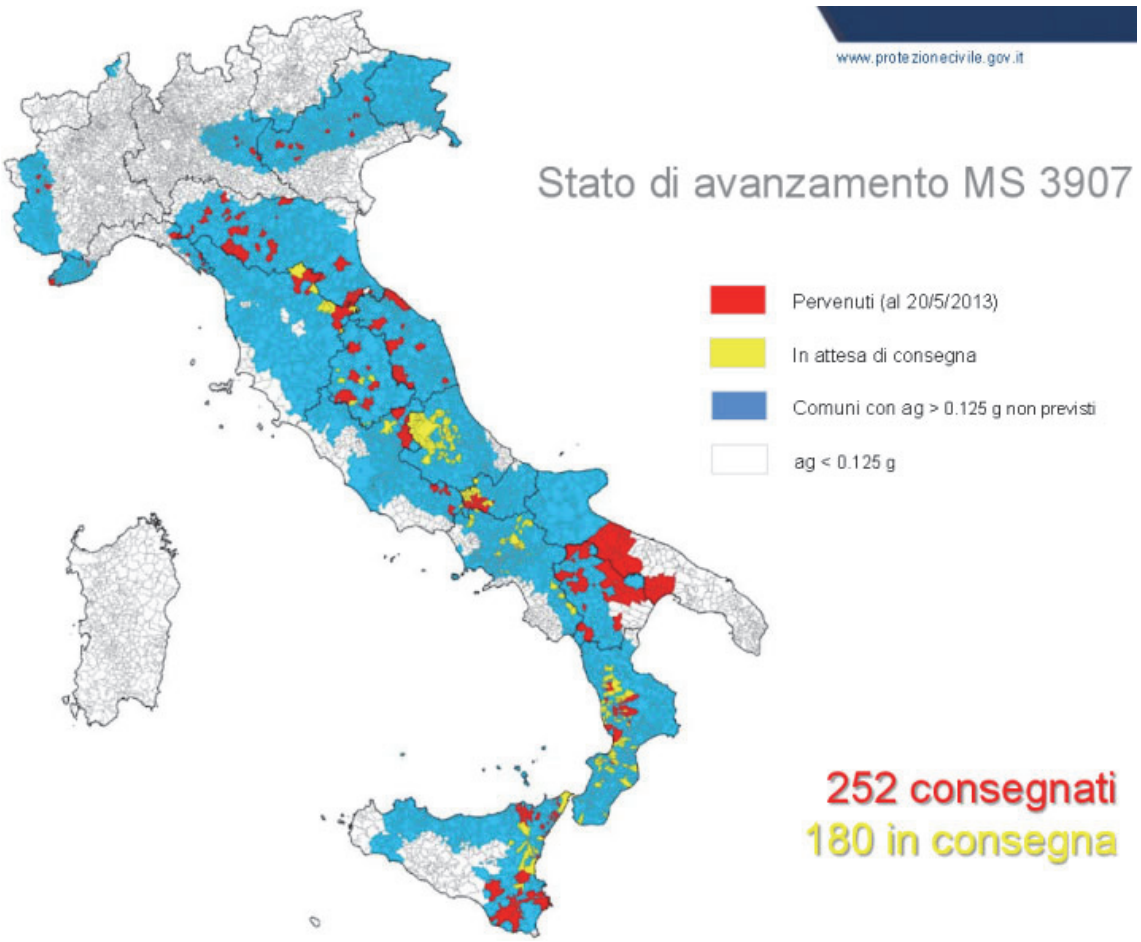


Fig. 4. State of progress of seismic micro-zonation studies and validations on 20/5/2013

5. CONCLUSIONS

In addition to reducing the loss of human lives, mainly in the highest seismic hazard areas (ag≥0.125g), the national programme of seismic micro-zonation studies (SM) and the ELC analysis has reached a broader spectrum of goals.

It has been able, in fact, to stimulate the attention of the citizens and administrators towards the issues of prevention (public and private building recovery, infrastructure recovery, seismic micro-zonation, urban planning and emergency) and to trigger a virtuous process that tends to increase the effects of the funds invested, through the request for co-financing of public administrations and citizen participation.

The institutional and technical activities undertaken in recent years have also led to an intense and effective collaboration between the State (DPC) and the autonomous regions and provinces, to the establishment of a work method among experts of various technical scientific extraction (ICMS 08, Earthquake of Aquila, SM Work Group), with the introduction of virtuous prevention processes for territorial planning, construction and emergency regulations (Art.11), and the involvement and cultural enrichment of geologists, engineers and architects with courses and seminars at a national and regional level, and agreements with professional orders.

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