CIVIL PROTECTION VS. EARTHQUAKE ENGINEERING AND SEISMOLOGICAL RESEARCH

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ABSTRACT:
It is very important that Civil Protection (CP) activities be carried out by using high level scientific procedures and technological means. Generally speaking, good reasons for a strong connection between research and CP are related to the use of the most advanced research results in order to get:
1) scientific consensus on evaluations that imply wide uncertainties;
2) optimisation of resource allocation for risk mitigation;
3) precision and rapidity of forecasting, for as much fast and effective as possible warning and rescue actions;
4) effectiveness in search and rescue operations;
5) optimisation of resources and actions for emergency overcoming.
As far as seismic risk is concerned, the Italian Civil Protection Department (ICPD) has involved the most important Italian scientific institutions on Seismology and on Earthquake Engineering. About 2000 researchers cooperate in scientific programmes funded by the ICPD, finalised towards objectives and products of use for CP. In this paper the following aspects are dealt with:
- organisational relationships between ICPD and scientific institutions for seismic risk;
- main research activities and related scientific products of immediate use for CP in the recent years;
- further needs and improvement for an "ideal" synergic relationship between seismic scientific community and CP organisations.

KEYWORDS:
Civil Protection, Earthquake Engineering, Seismology, Research, Prevention, Emergency

1. INTRODUCTION

Civil Protection (CP) organisations aim at safeguarding human life and health, goods, national heritage, human settlements and environment from all natural or man-made disasters. In order to achieve these objectives, for any concerned kind of risk, a comprehensive approach should deal with:

- Forecasting and Warning
- Prevention and Mitigation
- Rescue and Assistance
- Emergency overcoming

CP systems all over the world have different organisations and are differently finalised at the above actions and objectives. Quite often, only some of them, usually only those relevant to forecasting and rescue, are pursued by CP, risk mitigation and emergency overcoming being in charge of other organisations. However, it is very important that high scientific level tools, procedures and technologies be utilised when carrying out all these actions, due to the heavy consequences that inadequate actions can have.

Tools and technologies of high scientific level can be of effective use for CP only if they derive from a close cooperation between scientists and end-users, rather than from a simple commercial contract. It is necessary to establish a systematic relationship between research and CP, where CP demands are correctly transferred to the scientific community, so that the state-of-art can be improved and translated into results/products of actual use.

Moreover, CP operators have to acquire full cognition of the new tools and use them with competence and awareness of their potential.

Generally speaking, the link between CP and scientific community has important synergic implications. On the one hand, as far as the CP viewpoint is concerned, five good reasons for a strong connection between research and CP are related to:

1) reaching a wide scientific consensus on evaluations that imply large uncertainties, needed however to take prevention measures or to make sounded decisions to minimise the consequences of catastrophic events;
2) making right choices for the optimisation of the resource allocation for risk mitigation;
3) getting precise and rapid forecasting, to undertake as much fast and effective as possible warning and rescue actions;
4) using advanced operational tools which improve the effectiveness in search and rescue operations and, more generally, in post event activities;
5) optimising resources and actions for emergency overcoming.

On the other hand, apart from the evident advantage of getting significant funds for research activities, an important positive implication for the scientific community is the clear finalisation of some of their activities, which often leads to an enlargement, rather than a restriction, of the investigation perspectives, otherwise too often finalised mainly to the achievement of academic advancements. Moreover, it is worthwhile mentioning the ethical value of a research with direct and positive social implications.

With respect to the above considerations, the Italian CP system is quite peculiar, because all the above said actions are mostly in charge of national and regional CP organisations, all having the same institutional rank, and because there is a strong connection between CP and scientific community, which directly or indirectly participates to those actions for all kinds of risk (seismic, volcanic, hydraulic, hydrogeological, industrial, etc.).

As far as the specific field of seismic risk is concerned, the Italian Civil Protection Department (ICPD) has involved through contracts the most important Italian scientific institutions on Seismology and Earthquake Engineering: the National Institute of Geophysics and Volcanology (INGV), the Network of the University Laboratories of Earthquake Engineering (ReLUIS consortium) and the European Centre for Training and Research in Earthquake Engineering (EUCENTRE). About 2000 researchers are involved in scientific programmes funded by the ICPD, finalised towards objectives and products of CP use.

In this paper, the overall question of the relationships between CP organisations and scientific community will be discussed, by making reference to the Italian experience and dealing with the following aspects:

- organisational relationships between the ICPD and the scientific institutions for seismic risk;
- main research activities and related scientific products of immediate use for CP objectives in the most recent years in Italy;
- further needs and improvements for an “ideal” synergic relationship between seismic scientific community and CP organisations.

2. ORGANISATIONAL RELATIONSHIPS BETWEEN ICPD AND THE SCIENTIFIC INSTITUTIONS FOR SEISMIC RISK

The Law 225 of 1992 set up the National Civil Protection Service, in order to protect the integrity of human life, goods, dwellings and environment from damage or from the danger of damage deriving from natural disasters and catastrophic events. This Service is coordinated by the Prime Minister and is composed by all the state (ministries, army and police corps, prefectures, etc.), regional and local administrations as well as by many other public and private institutions and organisations in the national territory, which can play a role for CP purposes. With the Law 343 of 2001, the Italian Civil Protection Department (ICPD) is appointed for the coordination of

the operational CP activities of all the public and private organisations and institutions.

The Law 225 clearly states the strict relationship between CP and scientific community. It establishes that the CP Authority can promote studies on the forecasting and prevention of natural disasters and catastrophic events, and that scientific institutions and research groups having CP objectives contribute to the National Civil Protection Service, even through purposely done contracts.

Indeed, for the seismic risk, a strong link between CP and scientific community had already been developed much before, after the 1976 Friuli earthquake, with the Geodynamics Project, then continuing, from 1981 until 2002, with the studies made by the National Group for the Defence against Earthquakes. These projects, at that time coordinated by the National Research Council, involved the whole scientific community: both seismological and earthquake engineering research programmes were funded. A strong impulse was thus given to these research areas, that would not have, otherwise, significant chances of growing up. Practically all the researchers already active in those fields were involved and, what is more, their number continued to increase considerably year after year.

This continuous action produced a generalised growth of the seismology and earthquake engineering Italian community, and a widened multidisciplinary point of view was reached, due to the need of studying problems common to different scientific sectors. The results of these activities have been numerous and multifaceted. Generally speaking, they can be summarised as a widespread growth of the scientific knowledge on earthquakes, both in the seismological and engineering fields, and as the progressive development of a systematic approach to the various problems, from the definition of seismic risk, including the three components of hazard, vulnerability, exposure, to the design of new constructions and the retrofit of the existing ones. However, not all the research products were of immediate CP use, as many of the sectors involved were still in need of a progressive development of some basic aspects.

The reorganisation of the National Institute of Geophysics, that became National Institute of Geophysics and Volcanology (INGV - www.ingv.it) in 1999, and a Directive of the Prime Minister in 2004 determined a considerable step ahead in the relationship between CP and research. The Directive defines one of the ICPD missions as the promotion of studies and researches, as well as the development of products, for the optimal performance of the CP Functional Centres and the improvement of forecasting and prevention capabilities in real time of the CP system. The Directive also sets up the Competence Centres, and clarifies their tasks and appointment as the “subjects that provide services, information, data, elaborations and technical-scientific contributions in specific fields”. Previously, the Ordinance of the President of the Council of Ministers OPCM 3274 (2003) had charged the ICPD of promoting the research in earthquake engineering through (i) the setting up of a centre for the training and research and (ii) a network of university laboratories of earthquake engineering. Thus, INGV, EUCENTRE and ReLUIS became the reference system of Competence Centres on seismic risk for the ICPD. This system provides the most advanced scientific knowledge in Seismology and Earthquake Engineering, with the capability of producing considerable progress and organisation of the scientific information and of promoting a strong finalisation towards products for CP scopes.

The new relationships between CP and scientific community are based on a continuous cooperation and are characterised, in general, by a stronger finalisation to products of immediate use for CP, a clearer relationship between funds and products, and a modernisation of some research sectors in an international framework of research and training activities.

As far as earthquake engineering is concerned, the two Competence Centres, 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 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. These laboratories have now the facilities to make dynamic (shaking table) and pseudo-dynamic (reaction wall) tests on large full-scale structural models

(buildings up to 4-5 stories) as well as on large full-scale seismic devices. The ReLUIS consortium put them together in a network that, after an ad hoc agreement, also includes the Dynamic Laboratory of ENEA-Casaccia. In this configuration, the ReLUIS consortium is now the most complete national system in Europe for earthquake engineering experimental research, due to the variety and integration capability of the facilities for experimental tests on large full-scale structural models (see figure 1). The EUCENTRE foundation is an international reference centre for both training, also due to the synergy with the international Rose School, and the research on specific topics. EUCENTRE manages and implements the large lab facilities available at the University of Pavia, that were partly funded by ICPD.

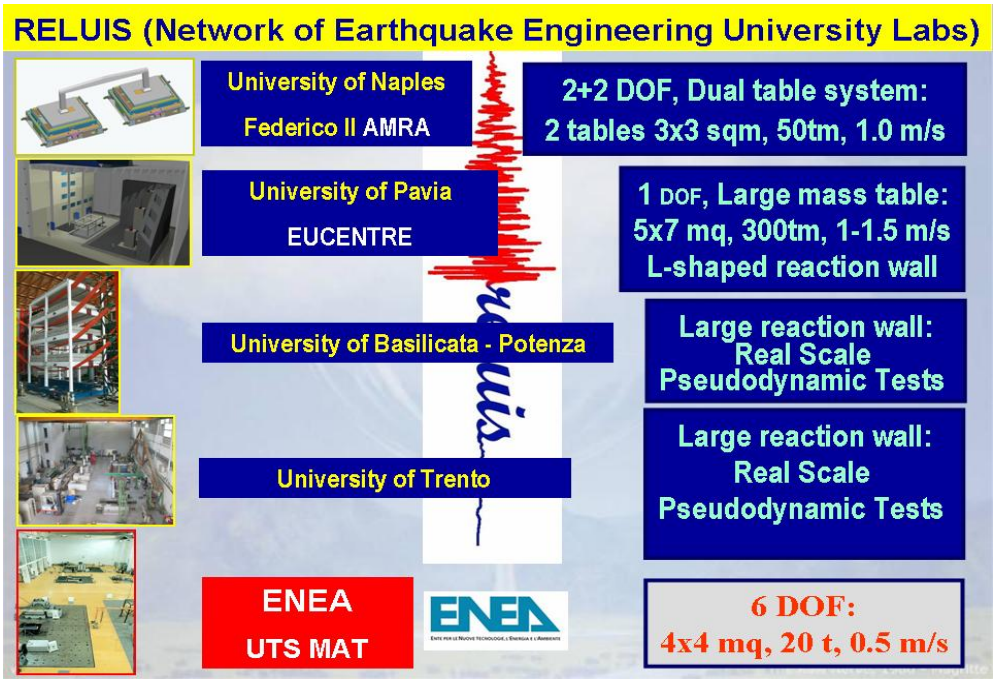

Figure 1. Network of Italian large experimental earthquake engineering facilities (including ReLUIS-ENEA agreement).

3. MAIN RESEARCH ACTIVITIES AND RELATED SCIENTIFIC PRODUCTS

The research activities carried out by the three Competence Centres are funded by the ICPD through three-year contracts, signed separately with each centre. In the following sub-paragraphs, research activities and relevant results will be shortly described by grouping them in the two large areas of earthquake engineering (carried by ReLUIS and EUCENTRE) and seismology (carried by INGV). Coordination within each of the two areas is assured by the Competence Centres and supervised by ICPD. Coordination between the two areas will be discussed in the following section 4.

Besides the results of the scientific projects illustrated below, it is worth to mention also the contribution of the Competence Centres to Divulgation, aimed at increasing the population awareness of seismic risk, the prevention culture and the preparedness to an event. Project “SV-EDURISK, educational paths on seismic and volcanic risks”, within INGV scientific programme, should be mentioned: a didactic laboratory for primary and secondary school students has been set up and proposed to several schools in Italy. The significant contribution of ReLUIS in the realisation of a demo transportable shaking table with two degrees of freedom, where 10-15 students can feel real earthquakes, also deserves to be cited. Both the EDURISK lab and the demo table have been included in the itinerant exhibition of DPC entitled “Earthquakes of Italy” (www.protezionecivile.it/cms/view.php?dir_pk=395&cms_pk=4033). This exhibition has scientific, historical and artistic character. It started its tour in 2007, staying for two-three months in each place, selected all over Italy among the ones that underwent significant earthquakes in the last century.

3.1.1 Seismological Research

The scientific activities in the seismological field are all coordinated by INGV, with the involvement of all the scientific seismological community. Every three years, a scientific programme is funded by ICPD. The programme is organised in projects, each of them carried out by several research units formed by scientists from different universities and scientific institutions.

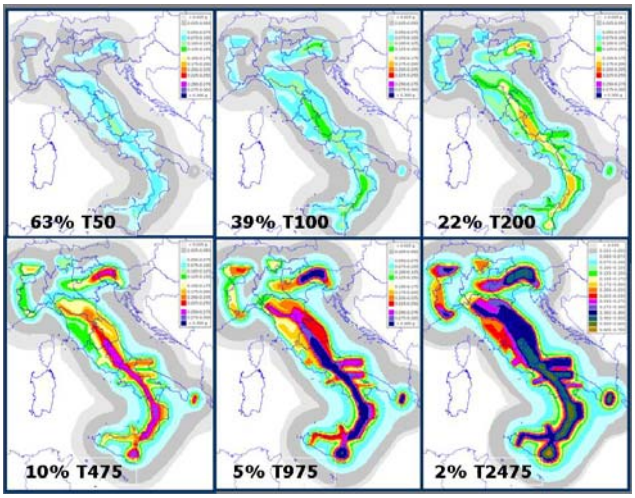

Figure 2. Hazard maps in terms of peak ground acceleration on stiff soil (ag) for different return periods (project DPC-INGV-S1)

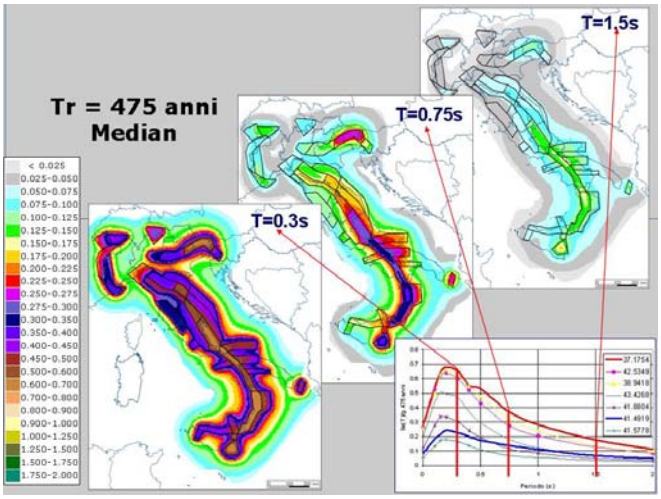

Figure 3. Hazard maps in terms of elastic response spectra on stiff soil (project DPC-INGV-S1)

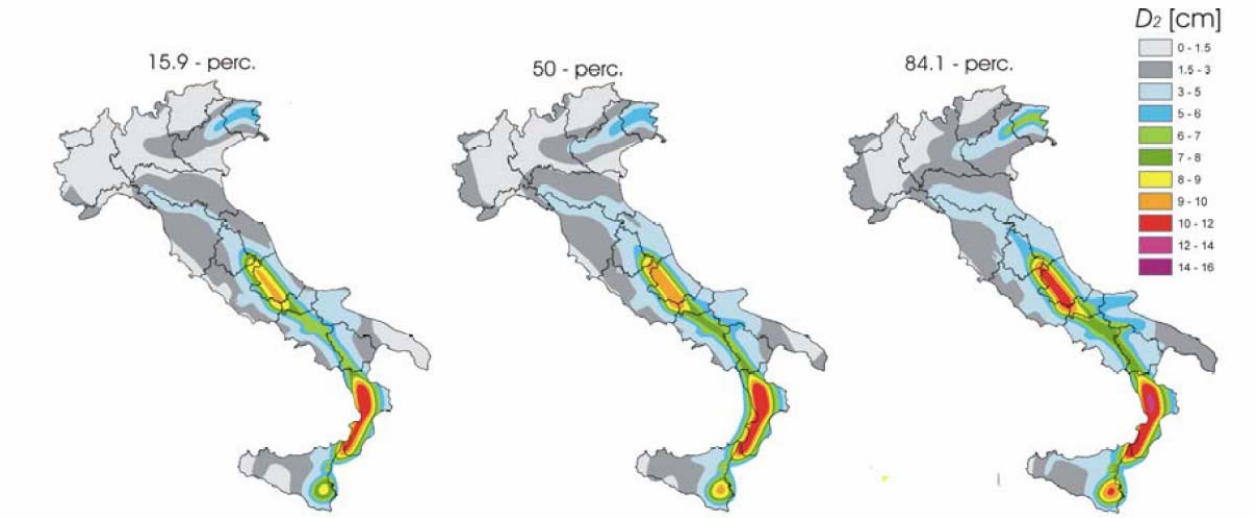

Figure 4. Map of spectral displacement at 2 s, for 475 years return period and stiff soil: 16, 50 (median), 84 percentile (project DPC-INGV-S5)

The previous programme, whose activities were completed in 2007, encompassed 6 seismological projects (S1 to S6; http://legacy.ingv.it/progettiSV/). The projects were relevant to several issues of interest for CP, and led either to immediately operative products or to results that are preparatory to tools for more detailed and reliable evaluations or predictions of hazard and risk. Among the immediately operative products, the results of projects S1 (Meletti et al., 2007) and S5 (Faccioli and Rovelli, 2007) deserve mentioning, as they consist of the national hazard maps in terms of peak ground accelerations, pseudo-acceleration response spectra on stiff soil and displacement response spectra, for different soils and return periods (from 30 to 2475 years; see figs. 2, 3, 4). The results of project S1 have been promptly exploited in the most recent version of the seismic code (Ministry

of Infrastructures, 2008), where the design seismic action is defined point by point in the map, for any geographical coordinates. In the seismic code, however, consistently with the spectrum shape proposed in EC8, the design elastic spectra are simplified, assuring the best fit to the spectra resulting from project S1. These simplified design spectra can then be described by using three parameters only (PGA on stiff soil a_g, amplification factor F_0, corner period T_C; see fig. 3). At the moment, the displacement response spectra maps obtained by project S5 are not included in the new code, but they could be in the future. Indeed they are indispensable tools for the application of innovative methods of analysis and verification more consistent with the actual seismic structural behaviour, which is displacement-controlled rather than force-controlled. It is worth to remind that ReLUIS and EUCENTRE are currently developing these methods.

Among the other projects completed in 2007, project S4 set up a tool for the rapid generation of shake maps, starting from the identification of the seismic source and the magnitude of the earthquake. It also exploits the shaking parameters (PGA, PGV, PGD) derived from the accelerometric networks managed by ICPD and INGV. The knowledge of a reliable shake map soon after (within some tens of minutes) the earthquake allows ICPD to make a reliable estimation of the possible damage to constructions and of the casualties, so that search and rescue resources can be optimally allocated and distributed on the territory. Project S6 realised for the first time a complete and unified database of the Italian accelerometric data (http://itaca.mi.ingv.it), providing important information on the stations and on the site characteristics, besides the waveforms and their main parameters. This result will satisfy the increasing demand for strong motion data of not only the scientific community but also the structural designers. Actually since 1972 ICPD has accumulated a large amount of strong motion data with its national accelerometric strong motion network (RAN), that had never been collected in a complete and well structured database, accessible through web. Project S2 was aimed at extending some databases, among which the database of the Italian seismogenic sources, characterised by the maximum expected magnitude and, if reliable, the activation probability in a given time interval. The results of this project are aimed at improving the hazard evaluation in the long run, for the next generation of hazard maps, but they are also of immediate use at regional scale, for instance for scenario analyses. The compilation of this database is obviously still in progress. Finally, Project S3 dealt with the preparation of guidelines for the development of seismic scenarios with different levels of detail; they were based on some test areas, chosen in order to make a methodological comparison in view of the set up of emergency planning or mitigation programmes at local scale.

The five projects set up within the new DPC-INGV research programme (http://www.ingv.it/l-ingv/progetti/), that is presently ongoing and will end in 2010, further develop some topics that either were not completed in the previous programme or still need to be improved, such as for the new project S3, which deals with the rapid estimation of the parameters and effects of strong earthquakes in Italy and in the Mediterranean area, or the new project S5, devoted to a further enhancement of the strong motion database, including the most recent records of RAN and of other networks, as well as more detailed data on the sites of accelerometric stations. The upgrading of the hazard maps obtained as a fundamental result of the previous programme is not an objective of the new programme. As a matter of fact, ICPD and INGV are moving jointly towards the attempt to realise an experimental dynamic model for the evaluation of the seismic hazard at national level and a further improvement of the knowledge of the seismogenetic potential in Italy, that represent, respectively, the objectives of the two new projects S1 and S2. Finally, the new project S5 is meant to support new activities, or to address some already existing, for the implementation of multidisciplinary monitoring systems of selected seismogenetic sources or areas, with the aim of enhancing the knowledge of the earthquakes generation processes and occurrence rates in Italy. The results of this project are evidently not of direct CP use, but this activity deserves attention, due to its high potential value in terms of detailed knowledge of the seismogenic structures, evaluation of geophysical and geochemical precursors, characterisation of the local response.

3.1.2 Earthquake Engineering Research

In 2003 a new seismic code and a new seismic classification were enforced by the ICPD, as an urgent measure after the earthquake of S. Giuliano, that killed 27 children; indeed the previous seismic code and classification were quite obsolete, their conceptual basis having been left unchanged during the last 20 years. The new seismic code was based on the version of Eurocode 8 available at that time (CEN, 2003), but many changes were made and a completely new part, concerning assessment and retrofit of existing buildings, was introduced. The new

code was applied on a voluntary basis for an experimental period that lasted until 2007, due to repeated postponements of its full enforcement.

A significant part of the research programmes of ReLUIS and EUCENTRE for the 2005-2008 period was related to (i) a practical appraisal of the new code, as well as to the setting up of possibly needed modifications, and (ii) the production of manuals and codes of practice, to support engineers in this passage of great transformation of the code. In the meanwhile, attention has been paid to innovative methodologies and technologies both useful for future implementation of codes and for the improvement of seismic risk assessment, post-event evaluation and early warning. The research programmes, still ongoing, deals with 5 great themes of earthquake engineering:

- the evaluation of the vulnerability of existing structures and the methods for its reduction, with particular emphasis for the structures that are most common and most critical for earthquake consequences, such as R/C and masonry buildings and bridges;
- the set up of innovative design criteria, in order to overcome a design philosophy too much based on elastic calculations and on the verification in terms of forces and stresses rather than on displacements and deformations, to improve the design of less common structures, such as steel and concrete-steel structures, and to develop concepts and tools for seismic-geotechnical design;
- the study of new technologies and methods for the seismic protection of structures, from seismic isolation, passive control and semi-active control to the use of fibre-composite, setting up analysis and design methods as well as making experimental verifications of them;
- the setup of tools for the seismic risk evaluation of and for the emergency management, with particular attention devoted to the development of databases for the seismic risk evaluation, the post-event scenarios, the definition of the priorities of intervention on inadequate buildings, the experimental damage assessment techniques, the structural monitoring and the “early warning” techniques for strategical structures and infrastructures;
- the design of peculiar structures whose seismic behaviour has been less studied in the past and therefore needs in-deep experimental and theoretical studies, such as R/C precast buildings and harbour structures.

In this research programme, about 130 research units have been involved; they are distributed all over the entire national territory, in all the about 40 universities where research groups of earthquake engineering are active. They actually constitute a national network of earthquake engineering research. Coordination and continuous information exchanges are assured through frequent meetings and workshops, some of them extended to a professional audience, as well as an annual plenary meeting organised by ReLUIS. Coordination between ReLUIS and EUCENTRE is assured by the activity of many EUCENTRE researchers within ReLUIS projects.

Finally, the training activity should be mentioned that is carried out by ReLUIS and EUCENTRE to support graduate and undergraduate designers. It is aimed at explaining the new methods of structural design and analysis required by the new seismic code. Some tens of thousands of professionals attended the refresher courses on seismic code, that complied with a predefined programme drawn up together with the ICPD. The courses were organised either by the two Competence Centres or by research groups involved in the scientific activities. Moreover, the web sites of ReLUIS and EUCENTRE provide useful tools for design, such as software, databases, scientific publications and manuals.

4. FURTHER NEEDS AND CONCLUSION

The long Italian experience of scientific research applied to seismic risk problems, finalised to the achievement of results for CP use, provides a positive balance. However, the synergy between the scientific and CP communities can be maximised only if the two worlds understand each other. This is feasible if each of them is able to understand the other’s language, needs, problems and objectives. Research institutions have general objectives, duties and programmes that obviously do not fully coincide with those of CP organisations. For this reason a smart interface between research and CP is necessary, which implies the need of a good scientific

background by CP representatives and of scientists lively interested in solving concrete problems of applied research, in order to:

1) define suitable objectives of the ICPD-funded research, so that they can be fully respondent to the CP exigencies and aligned with the state-of-the-art in the related field,
2) set up programmes whose costs are compatible with the available economical resources,
3) utilise correctly the results by taking them into account in the general procedures and methods of CP,
4) cooperate to develop the programmes, in order to better understand actual problems and find the best solution for the CP aims of the projects.

The multidisciplinary character of the seismic risk requires a strong interaction among scientists who deal with different scientific subjects (seismology, geophysics, geology, engineering, architecture, urban planning, economy, sociology, etc.) and are not always used to work together. Traditionally, there is a strong separation between seismologists/geologists and seismic engineers, that actually are the two largest scientific communities involved. In Italy, for more than twenty years a unique research group was devoted to seismic risk research, while in the last years three different Competence Centres have been carrying out separately the seismological and the earthquake engineering research. Although the past experience of a unique group was not so effective from this point of view, as joint seismology-engineering projects were rarely activated, now the presence of more Centres could enhance the separation between the research areas, further increasing the distance between the two communities. On the contrary, CP needs do require a multidisciplinary approach; it is therefore necessary to favour and increase, for some aspects, the integration of the research between seismological and earthquake engineering communities. Such integration could be achieved through joint projects and interaction on interdisciplinary themes, and through workshops dedicated to multidisciplinary interface problems.

Apart from INGV, that has the responsibility of the seismic surveillance and in this sense it is fully involved in emergency phases, until now large parts of the Competence Centres scientific activities have been mainly devoted to prediction and prevention problems. The participation of the scientific community to the emergency phase was not explicitly considered in the previous contracts and therefore, it was conducted on a voluntary basis, without a predefined organisational scheme, this implying possible dissipation of energies and superposition of activities. In the future, a structured involvement of the Competence Centres should be programmed even for the emergency phase. The main activities shall be related, for example, to the monitoring of soil and structures with mobile instrumentation (in order to rapidly evaluate the effects of aftershocks), to the immediate surveys of the earthquake effects on the natural environment (landslides, liquefactions, soil fractures, surface faulting, etc.) and on the built environment (macroseismic survey, damage and usability assessment of buildings, monuments and infrastructures). Some of these activities were already carried out by the scientific community, but with a not clear interface with CP and not a clear finalisation. It is worth to emphasise that also in the post-event activities important synergies could be established in the cooperation between research and CP, as earthquakes represent full scale real experimental tests of geophysics, geology and structural engineering, and they can provide significant and stimulating hints for scientists. In order to maximise efficiency and usefulness of on-site activities for CP organisations, suitable telecommunication connections between the CP operative structures (functional centre, operative hall) and the competence centre shall be established.

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