CHAPTER 1
ASSESSING AND MANAGING EARTHQUAKE RISK. AN INTRODUCTION

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1.1. Organization of the Book

This book compiles in a single volume different aspects directly related to earthquake mitigation. It is intended to initiate graduate and undergraduate students in the field of earthquake damage assessment and mitigation as well as to provide updated information for professionals dealing with these matters. In particular, it is addressed to students in applied Geosciences who need to have some skills in more engineering oriented topics and also for Engineering students that need to have some background on Engineering Seismology.

Students and professionals with initial academic background in Geology, Geophysics, Geotechnical and Civil Engineering, System Analysis, Geography or Architecture are in optimal position to acquire from this book a good background in earthquake risk assessment and management.

This volume also shows how geo-scientific and engineering knowledge is transferred to Civil Protection and insurance agents, and how the close collaboration between geoscientists, engineers and emergency managers can contribute to more efficient earthquake mitigation.

Following this chapter, the book is organized into five main parts:

Part I *(Earthquake hazard and strong motion*) deals with the concepts involved in the seismic process from source to site, including the most recent advances in the techniques of hazard analysis (Chapter 2), strong motion representation (Chapter 3) and microzonation (Chapter 4). Chapter 5 deals with the problem of interaction of buildings with neighbouring media.

Part II (*Vulnerability assessment)* is devoted to the analysis of vulnerability of dwelling buildings (Chapter 6), historical buildings (Chapter 7) and lifelines (Chapter 9), while (Chapter 8) is dedicated to experimental methods for determining the fundamental frequency of buildings.

Part III *(System analysis and Risk)* looks at the seismic risk problem from an individual level (Chapter 10) to an integrated system level (Chapter 11), with hospital networks as an example (Chapter 12).

Part IV *(Managing earthquake risk)* develops the main concepts of mitigation, through construction and control practices (Chapters 13 and 14), early warning and rapid damage assessment (Chapter 15), emergency management (Chapters 16 and 17), insurance (Chapter 18) and reinforcing the building stock (Chapter 19). Chapter 20 describes some new available technologies.

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Finally, Part V *(Case studies, initiatives and experiences)* presents in Chapters 21 to 23 examples of applications in which the scale of work and the methodologies are different, allowing comparisons among various seismic scenario situations.

An extensive list of references corresponding to all chapters, assembled at the end of the book, will help the reader interested in further details on the covered topics.

1.2. Natural Hazards. Earthquakes

The so called “natural” disasters, that is, those related to phenomena of Nature, have caused throughout the centuries great convolutions in the process of human development. Even though advances in science and technology have produced a great deal of knowledge on the causes of those disasters, human deaths in the world per million inhabitants are only slightly decreasing with time, but the economic losses have dramatically increased in the last decades. The rise in world population and the complexity of societal organisation, among others, are factors that may explain this unfortunate fact. Inadequate non-sustainable use of the territory and present day inadequate construction practices, especially in developing countries, are clear causes of the too frequent “natural” disasters.

In general, it can be stated that society has become more vulnerable. Natural disasters reveal the fact that our economic development is unacceptably brittle, too vulnerable to the normal behaviour of Nature.

Therefore, when we speak about natural hazards we refer to those events that are triggered by or related to phenomena of Nature.

Man-made accidents dominate the entire panorama of death toll around the world. For example, the number of deaths from road accidents in the world for 2003 (2.2 millions) is still larger than the total number of deaths from earthquake activity during the 20th century (1.5 millions). However, the number of worldwide victims from earthquakes is high when compared with other natural hazards, as shown in Figure 1.1.

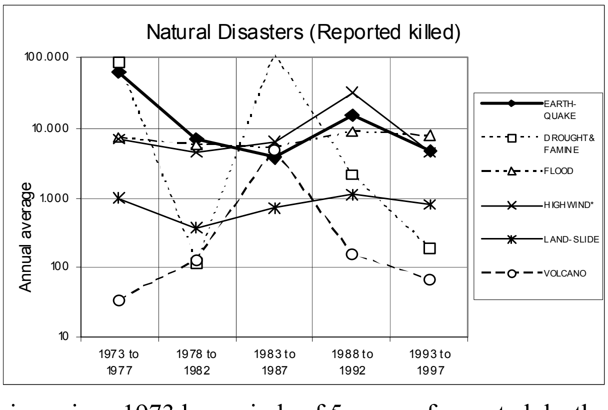

Fig. 1.1. Comparison since 1973 by periods of 5 years of reported deaths by earthquake, drought and famine, floods, high winds, landslide and volcano (Oliveira, 2003)

Table 1.1. reports the world's largest earthquakes since 1900 with respect to number of deaths (larger than or equal to 10 000), also showing the region of occurrence and the corresponding magnitudes. Both, from Figure 1.2. and Table 1.1. it is interesting to note that this period of time is characterized by an annual average of 15 000 deaths with two main fluctuations (modal values), the largest in the period 1900 to 1940 and another with a larger value in the decade of 1970-80.

Figure. 1.2. shows the number of total deaths from the greatest earthquakes that occurred in the XX century. Although the number of victims has a tendency to decrease with time, the economic losses are increasing significantly (see Chapter 18 of this book).

Table 1.1. World earthquakes since 1900 with number of deaths greater than 10 000

Year	Region	Deaths	Magnitude		Year	Region	Deaths	Magnitude
1905	India	19000	8.6		1960	Agadir, Morocco	12000	5.9
1906	Chile	20000	8.6		1962	Iran	12000	7.3
1907	Central Asia	12000	8.1		1968	Iran	10000	7.3
1908	Italy	70000	7.5		1970	Yunnan, China	10000	7.5
1915	Italy	29980	7.5		1970	Peru	67000	7.7
1917	Indonesia	15000	-		1972	Nicaragua	10000	6.2
1918	China	10000	7.3		1976	Guatemala	23000	7.5
1920	China	220000	8.5		1976	Tangshan, China	242000	7.8
1923	Japon	142807	7.9		1978	Tabas, Iran	25000	7.4
1927	China	80000	8		1985	Mexico	10000	8.1
1932	China	70000	7.6		1988	USSR (Armenia)	25000	6.8
1933	China	10000	7.4		1990	Manjil, Iran	40000	7.7
1934	India	10700	8.4		1999	Izmit,Turquia	30000	7.4
1935	Pakistan	30000	7.5		2001	Gujará, India	20000	7.7
1939	Chile	28000	8.3		2003	Bam, Iran	26796	6.6
1939	Turkey	32700	8		2004	NW Sumatra	300000	8.9
1948	Ashkhabad	19800	7.3					

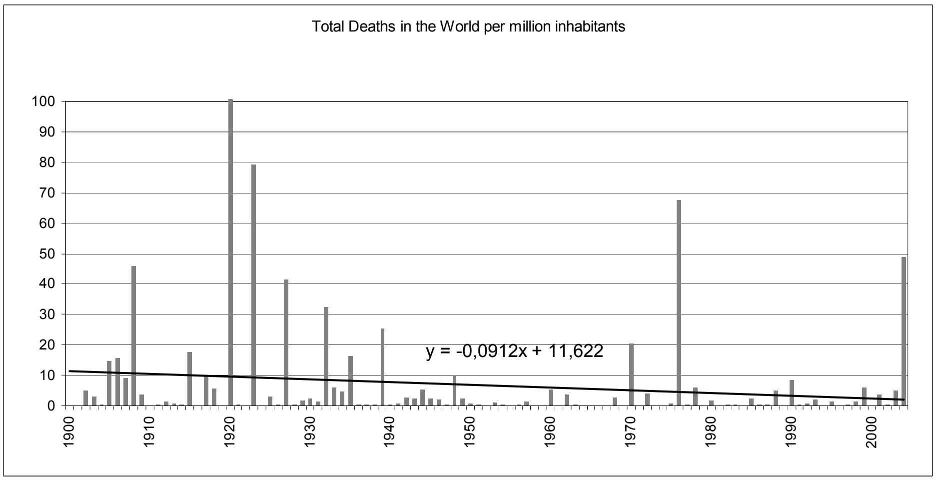

Fig. 1.2. List of "notable" "Great" earthquakes of the 20th century by number of deaths per million world inhabitants (data from Coburn and Spence, 2002; Samardjieva and Badal, 2002 and USGS web site)

The number of victims and the economic losses from earthquakes are strongly dependent on the seismic magnitude and focal distances to urban areas. Moreover, the relation between economic losses and number of victims is dependent on social and economic factors associated to the level of development of the affected country. This can be seen in Figure 1.3, which shows the human losses as a function of magnitude for the major earthquakes in the 20th century. For the same range of magnitudes a larger number of victims occur in less developed countries. On the other hand the larger economic losses occur in the most developed countries, as seen in Figure 1.4.

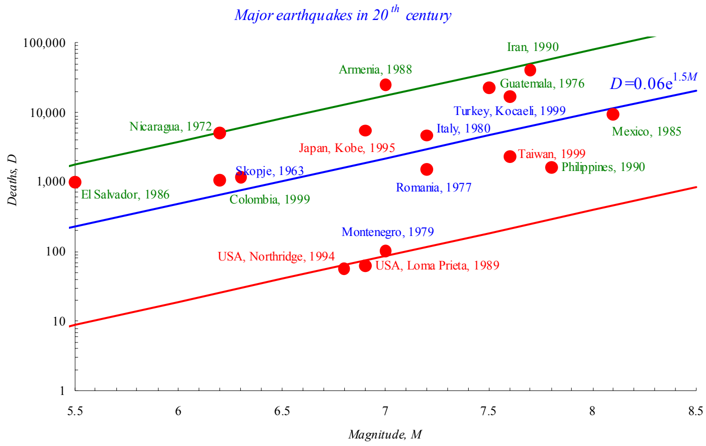

Fig. 1.3. Human losses as a function of magnitude (Vacareanu et al., 2004)

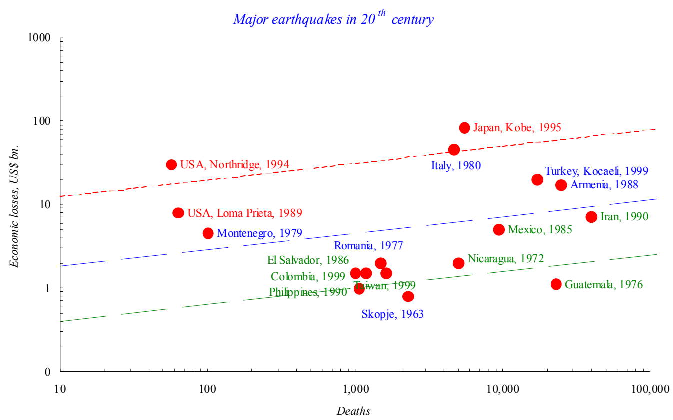

Fig. 1.4. Economic versus human losses caused by earthquakes (Vacareanu et al., 2004)

1.3. Earthquake prediction and prevention

The seismic phenomena have been largely studied by seismologists, comprising a large number of disciplines, approaches and knowledge. From the beginning of time, prediction of natural phenomena and, in particular, earthquakes has been one of the objectives of human kind. However, the complexity of the rupture processes at the origin of earthquakes does not yet allow science to produce earthquake predictions in a reasonable term period that would satisfy our needs: to know the time, location and size of the next important event within narrow and accurate windows. Furthermore there are some present scientific tendencies that point to the nonlinearity of the phenomenon, with the consequence that what is commonly understood as prediction may not be possible.

Even in the case of a hypothetical precise prediction at short term (days or weeks) which would allow saving human lives by moving the population to safer places, economic losses would not be avoided because of the impossibility of protecting structures and the economic fabric at such short notice.

In recent years, with the development of rapid transmission and treatment of data, it has been possible to design early-warning systems, which, after the occurrence of an earthquake, produce information about the possible arrival of strong seismic waves. In some cases, when the source is distant enough from urban areas, a few tens of seconds can be used to trigger security systems of some critical facilities (see Chapter 15).

In any case, it is more and more possible to produce information about the possible effects and their geographical distribution by an early scenario simulation (see Chapter 10), in order to speed up the intervention of emergency services acting to rescue the populations (see Chapters 16 and 17).

On the other hand, prediction in the medium and long term (tens to hundreds of years) is routinely used for assessing the seismic hazard at regional or local levels and for specific sites with critical facilities, evaluating the more exposed zones and quantifying the possible seismic actions (see Chapters 2, 3, 4, 5 and 14). This constitutes the first step of the strategy of *prevention*. In fact this is, at the moment, the only way to prepare for earthquakes.

An adequate strategy of prevention should include three main principles: (i) acknowledgement of the seismic phenomenon and its consequences in the built environment; (ii) assessment of the risk in both the seismic hazard and vulnerability of all components of the built environment; (iii) awareness of the importance of these assessments and putting in practice different actions in order to mitigate the estimated risks. Among these principles, the first two are of scientific and technical nature and they are developed in great extension in the first parts of the book (Chapters 2 to 12). The third one has an important political component and the technical aspects are introduced below and developed in Chapters 13 to 20.

1.4. Construction practices and urban planning

The most efficient way to mitigate earthquake risks is through an adequate construction practice and urban planning. In both cases for most countries, codes, either for construction and urban planning, define the minimum requirements or recommendations for a "good performance" in the face of a possible seismic action that may occur during the life-time of a given construction.

1.4.1. NEW CONSTRUCTIONS AND EXISTING BUILDING STOCK

New construction should reflect the knowledge and good practices of present day developments. This means that a society, wherever its makeup, should not build without the necessary resources to provide safe structures. Seismology, Geology and Engineering have all the means to do that at a reasonably low price compared to the price without using them. Quality control has to be practiced in a very strict way in order that everything built from now onwards can be considered safe in all senses as a heritage of security for the next generations. To accomplish these requirements extensive campaigns for policy changes should be promoted especially in countries with poorer knowledge and capacities. Simple, easy to apply and efficient techniques have to be implemented.

1.4.2. BUILDING CODES

Building codes and "good building practice" has been throughout the decades the only effective way to mitigate earthquake damage (see Chapter 13). Historically they were developed upon the construction knowledge accumulated by generations that suffer the action of earthquakes. The developments of science and technology through the 20th century, especially in the last 20 years, has led to complete new formulations of building codes, adapted to proven construction standards. Present codes are instruments of great use in all countries and should constitute the most important form of quality control in earthquake resistant construction.

The philosophy of codes has changed in recent years creating a more stringent concept of life-save and introducing the concept of minimization of certain types of losses, via the concept of performance. This last criterion depends very much on the type and importance of a facility. Vision 2000 (SEAOC, 1995) introduces this philosophy and tries to apply it to common construction (the housing stock), to important structures (schools, places of large concentration of population), and to very important structures (hospitals, decision centres, etc.). Another category of facilities should have a very special treatment due to the critical consequences in case of partial failure (critical structures, power plants, etc.). Figure 1.5 shows the performance stage for different frequencies of events (probability of occurrence).

The philosophy of codes has changed quite significantly in the last 50 years. The first generation of codes in the 1950´s took as their main goal the preservation of lives only, for a low probability of occurrence. But the latest generation follows very much the "performance criteria" as referred in Figure 1.5, requiring the verification of "performance" for different levels of ground motion. Chapter 2 discusses this subject under the concept of acceptable probability of occurrence of that risk, i.e. what is acceptable or unacceptable risk for the community and how far can we go with codes.

As far as legal character of codes there are various statuses among countries and among regions. In many countries in Europe codes are mandatory rules (Spain, France, Italy, etc.), while in the USA great differences do exist from state to state, in many cases codes are not more than recommendations.

	Fully operational	Operational	Life safe	Near collapse
Frequent	▲			
Occasional	▼	▲		
Rare	●	▼	▲	
Very rare		●	▼	▲

▲ Basic facilities
▼ Essential or hazardous facilities
● Critical facilities
unacceptable performance

Fig. 1.5. Performance of construction in function of probability of occurrence

Freeman (2004), analysing the performance of properly designed and constructed buildings, concluded that there are several reasons to explain why so many buildings survived with relatively little or no damage, given the large strong motion observed near those buildings. Those reasons for better performance are due to some conservatism in design, to excess of vertical capacity which increases lateral resisting forces, and to the experience of engineering design that can anticipate the potential for weak links and, consequently, provide alternative loading systems.

1.4.3. INSURANCE

Insurances (public and private), differentiating the premium, may contribute to control the quality of design and construction. Several models for the application of insurance are available and practiced throughout the world (see Chapter 18). Essentially, one can have centralized bodies as practiced in Spain by the Consorcio de Compensación de Seguros (Nájera, 1999), or a moderate centralized scheme such as the Solidarity Fund created in the EU in the aftermath of the large Central Europe floods of summer 2002. But the most practiced case is the existence of individual national or international companies with pools through international re-insurance. All these schemes could help to increase the public awareness towards seismic risk, creating a culture of risk prevention. It should be mentioned that for large installations it is already current practice to have expert judgement on these matters (see Chapter 14). It is now necessary to extend this policy to the more common types of buildings. Private and public interference in these issues is a matter of political environment, but should stay outside the basic problem of quality control.

1.4.4. URBAN PLANNING

Urban planning is an important component of earthquake risk mitigation. One can say that, in extremis, engineering and scientific/technical knowledge can overcome all difficult natural environments. But this may imply important costs in design and construction and be always a less equilibrated solution. Urban planning should define better uses of the territory in view of all possible threats, setting limits to the types of construction, layouts and size or defining more detailed seismic action for that environment, envisaging the possibility of excluding high level hazard zones. Urban planning may establish the degree of intervention in an existing block of buildings, the need for reinforcing, etc.

But a great deal of application comes from integration into urban planning of land use restrictions related to other effects beyond the direct ground motion ,such as the influence of known active faults, the induced phenomena of liquefaction and landslides, but also the tsunami flooding, flooding from dam failure, etc.

An example of an important development of rules related to municipal urban planning has been carried out in France by the Plans for Prevention of Risk (PPR), whose strategy is published in *Commissariat General du Plan* (1997). An important number of municipalities have developed their own local Plan during the last few years.

1.5. Emergency planning and managing

Civil Protection bodies are the agencies of larger public impact and visibility, responsible for the actions of earthquake risk mitigation. Emergency preparedness is the direct consequence of a good definition of hazard, vulnerability and risk assessment. Planning rescue operations, including transportation of injured, managing homeless problems, providing basic services, etc., and managing post-events in all their ramifications is of most importance for reducing the suffering of the affected populations and in returning disrupted lives to a normal standard. Chapters 16 and 17 elaborate on these multiple issues and Chapter 21 to 23 present several case studies dealing with cities, metropolitan areas and large regions for scenario evaluations.

1.5.1. PLANNING

Planning requires a prior definition of the seismic scenario or collection of seismic scenarios. For each one, the effect of the simulated motion is treated and transformed into variables to be used in the planning of all operations. Planning should consider the zones more prone to different incidences, and prepare logistic and field exercises to simulate situations that may happen in the case of a real earthquake.

1.5.2. MANAGING DISASTER RECOVERY

Managing an earthquake disaster has two essential components: the one right after the earthquake (the following few hours) and the one in its sequence (few days or weeks). The first one deals with all the operational measures to be taken in relation to the planning established, which includes a fast assessment of damage evaluation. Chapters 10, 15 and 20 devote a great deal of their contents to this subject. The second component has to do with the actions to be taken in order to lead to resumption of normal life (see Chapters 16 and 17) Detailed field surveys for precise evaluation of damage distribution are among the actions to be taken for deciding building occupation and urgent building intervention.

Rapid damage assessment after the occurrence is an essential part of the emergency process. Indeed, knowledge of the areas more affected by the earthquake should be consolidated in the shortest time possible. This requires a fast and accurate assessment of what has occurred, where and what type of problems should be addressed. For instance, the suffering of the populations can be slightly mitigated if information is given with precision, injured population is recovered at the earliest possible time, the homeless are transported to temporary shelters. The rapid damage assessment tool should help in determining which areas are more affected, the blocks of higher damage constraints in emergency road circuitry, buildings with higher concentration of victims, structures in danger of collapse due to some aftershock activity and needing immediate shoring, etc.

At other levels, insurance companies may start understanding the part of their portfolio that has been affected, lifeline agents can check the degree of interruption of operation of networks (telephone, gas, electricity, etc.), industrial agents can start the inventory of impacts in their activities, etc. All them are in better position for defining policies for intervention.

Modern technological developments can provide Civil Protection and other managing and security bodies with new forms of mitigation such as the seismic Early Warning systems (EWS). These systems are essentially of two types. The most widely accepted EWS takes advantage of real time modern seismology and deals with the lead time one can gain after the onset of an event by identifying from the first seconds of the P-wave the size of the S-wave which will arrive at a later stage. If the distance that the waves travel to a site is sufficiently large, one can gain tens of seconds and be able to send information prior to the arrival of the large S-amplitudes (Allen and Kanamori, 2003). Depending on the gained time, this technique will allow launching of important actions, such as shutdown of industries, closing networks, stopping dangerous activities, or preparing for active control of constructions. These new ideas are already being practiced in several locations as test cases, the most known one being the system for stopping the Sinkansan train in Japan. Chapter 15 will present the most recent advances dealing with these technologies which require well coordinated efforts between instrumental seismology, communication science and technology and engineering knowledge on how to use the information.

A second type of Early Warning Systems is used for tsunami alerts. In this case, the time to send the alert may be much larger depending on the distance that ocean waves travel. An alert of this type has already existed for many years in the Pacific Ocean (http://www.prh.noaa.gov/ptwc), for waves travelling during several hours to reach the target, but in other situations the times are less than half an hour. To be effective in these cases, good EWS should also be implemented with the most modern technological knowledge.

The December 26, 2004 M9.0 NW Sumatra earthquake, with more than 300 000 deaths, is the most tragic example of a tsunami effect in modern times. It is clear that the use of an EWS conjugated with adequate preparedness would have saved a large number of lives. Even though not directly addressed in this book, this topic is of most significant relevance in mitigating earthquake risk and should be analysed in great detail.

1.6. Reinforcing and reconstruction of the building stock

Reinforcing the most vulnerable construction and upgrading critical facilities is the best way to prepare society for future earthquake events. If an earthquake occurs, reconstruction should be practiced following the most well known principles and techniques. Reinforcing is a large burden to be taken up by various generations but cost-benefit analysis may indicate that, in the long run, it is the best policy to follow. Chapter 19 deals with this matter and presents practical situations using new scientific technologies, with particular emphasis on action in the case of low rise old masonry buildings. A construction that can resist seismic action to an adequate level will survive the earthquake, probably keeping its operational integrity. Damage may occur in some cases but casualties are reduced tremendously. Even in the worst cases, the housing facilities can be used right away, avoiding an enormous amount of homeless.

A programme for reinforcing has to be planned carefully in order to optimize resources and establish priorities through time. For instance, schools and hospitals are in the first line of priorities, followed by certain networks (lifelines). Housing, construction of cultural value, etc. are matters of a different kind. The first has to deal with private/public ownership, the second with the level of cultural value attributed. But, in all cases, an accurate evaluation of (i) the seismic vulnerability, (ii) the probability of surpassing some damage limit state, (iii) the cost of the intervention and (iv) the benefit produced has to be assessed.

Policies on rent, incentives, market expectations, architectural/historical values, insurance, land-use regulation, etc., play decisive roles on decision-making about this issue.

1.7. Philosophies and policies

Philosophies and public policies arise from human attitudes that evolve rapidly with the course of events. Historical documentation reveals the influence of earthquake impacts on the ways in which communities respond to mitigate their actions. Looking only at the last decade, one recognizes that the philosophy of modern codes is changing rapidly toward more adequate response to the problems that arise. We can cite many examples of structures that suffered no damage in circumstances where they would previously have been severely harmed.

Similar arguments can be brought in relation to public policies. Nowadays, the California law requires retrofit of special structures to be made within a certain limited time period.

“Field-Acts” and “Bills” have been the legal instruments in California to fulfil some of these compulsory requirements. The oldest “Alquist-Priolo Earthquake Fault Zone Act”, signed into Law December 22, 1972, concerns the location of schools and is more than 30 years old. The recent “Seismic Hazards Mapping Act” of 1990 defines land-use areas and the “California State Bill” of 1953, dedicated to hospitals, was updated in 1995 after the Northridge 1994 earthquake.

Retrofitting in certain seismic environments is being initiated. In Europe policies tend to change only after momentous events. The most recent case is in Italy, with the new legislation "Nuova Ordinanza, 3274" of 20/03/2003, which revises many sensible points of acceptable risk. This movement towards an updated legislation is the political response to the impact of the Molise (Italy) 2002 earthquake.

1.8. Lessons learned from recent earthquakes

In the past decade, many lessons were learned from earthquakes. In fact, not only large and diverse types of events occurred but also the monitoring of the seismic process has become very detailed. These circumstances allowed a better understanding of many of the parameters entering in the characterization of, for instance, ground motion (see Chapter 3), site effects (see Chapter 4), damage quantification (see Chapter 10) and the impact of earthquakes in more qualified terms. Also, emergency responses in terms of its achievements (see Chapters 16 and 17) were characterized in a more effective form, with clear identification of zones of success and zones of failure.

So, in almost all topics new information can be used for better characterization of the whole process and for calibrating the different models developed throughout the years.

1.9. Political considerations

Our scientific and technical knowledge has improved considerably in the last decade. This is clearly shown by many technological achievements, by the number of scientists devoted to these subjects with an excellent research production provided through a large and diverse number of research programmes and national and international initiatives, and by a huge amount of publications (books, specialized journals, frequent international conferences, meetings, workshops, etc.). These scientific achievements have led to an increase in e efforts towards the assessment of hazard and vulnerability but, only very recently, has political awareness gained some visibility, in particular in the wealthier earthquake prone countries.

It is clear that much is still needed to understand seismic phenomena and the technical needs of varied types of constructions and facilities. But, on the other hand, a great effort has to be made to provide public information which will contribute to an increase in decision-makers' awareness, so that they can support public and private actions leading to the mitigation of risk. The final word in prevention is to develop programmes and initiatives, by using the tools developed in scientific/technical circles, to avoid "damage" and "collapse" of individual constructions and to avoid the stoppage of "operation status" or "collapse" of network systems. These steps can be taken prior to an earthquake occurrence, by reinforcing the most vulnerable constructions, and consequently, reducing their probability of failure.

Bachmann (2004) asks the engineering community if it is doing the right things, and what policies it is pursuing to achieve a substantial reduction of seismic risk. He advocates that, to reduce casualties significantly in the third world countries, the best policy is to apply simple construction technologies that have been well known for a long time to withstand earthquake action.

As for new construction in developing countries , the scientific and technological advances of recent codes are good enough to prevent large problems if quality is assured. In the cases with large ancient housing stocks, the policy of retrofitting and the use of modern control systems depend very much on the hazard level. Simple and cost-effective techniques are not yet sufficiently developed to be accepted by these communities in general.

1.10. Education and mass media risk communication

This important topic is perhaps the one that might be the most effective to increase public awareness of the risks one faces in zones of high potential for earthquake activity. Increasing the number of people who can understand the risks associated to their lives and can learn how to cope with them in a conscientious way is the most effective form of reducing disaster impact (Bolt, 2004).

Prior-to-the-event awareness may press decision makers to take the most adequate decisions on time, such as launching policies for the reinforcement of the most vulnerable/risky structures.

An integrated information system for disaster management is a comprehensive way to cope with emergency post-event, using simulators for training disaster scenarios, e-learning as a form to divulgate concepts, actions, and a data-archive to bring together all available post-event information.

Recent initiatives emphasize the need for increasing the quality of communication, so the Euro-Mediterranean Forum on disaster reduction and a project on communication on Natural Risks in the frame of the Western Mediterranean region published a Decalogue of recommendations:

http://www.rinamed.net
http://www.proteccioncivil.org/informes/formediterraneo2003/declaration_madrid.htm.

1.11. Definitions of some basic concepts

Seismic process – Deals with the occurrence of an earthquake event and the process of wave propagation from the source to the site. At the origin, one is interested in characterizing the Time of occurrence, the location of the source (Space – focus, fault structure) and the Size of the phenomenon (magnitude, rupture properties and its kinematics, etc.). For the wave propagation, besides the source rupture, one needs to know the outer structure of the Earth from the source to the site.

Ground motion – The movement of the Earth surface caused by the wave passage. This movement involves the complexity of source mechanism, especially if we are in the near-field (at a distance comparable to the dimensions of the rupture), the characteristics of the medium travelled, and the geometric characteristics and mechanical properties of the geological stratum around the site under analysis.

Hazard assessment – Gives the probability that a certain parameter of ground motion (MMI, PGA, Spectra) or, in a more general case, of the seismic process, will be surpassed within a lifetime period.

Site effects – Changes in the ground motion propagating near the site, in amplitude, frequency content and duration, relatively to the motion at a “hard” lower layer, due to the geometric characteristics and mechanical properties of surface layers surrounding the site, especially for cases of soft layers and complex geometries. For strong motions the nonlinear behaviour of soil layers may take place, altering them significantly.

Other geotechnical problems – Liquefaction, landslide, lateral spreading, compactation: in certain geotechnical conditions other phenomena may take place as a consequence of the wave passage, causing mass movements of small to large extension.

Site-city interaction – Possibility of a "global" interaction between all the buildings of a city and its subsoil.

Tsunami – Sea wave caused at the earthquake source due to the vertical component of the fault rupture offset, or due to some important sequential mass movement at the sea-bed. When arriving at the coastal shoreline this wave becomes of large height hitting the land or acting as a rapid tide with important “run-up and run-down” if it enters a harbour or large river mouth.

Vulnerability – Degree (level) of performance of a system (engineering structure, network, social group, etc.) under a certain level of seismic action. A more vulnerable system is the one that, for a given action, cannot perform so well as another one.

Fragility – Similar to vulnerability but where the performance is viewed in a statistical way.

Damage (victims, casualties) – “physical damage”: deaths, injures (severe, light, etc.), homeless, damage to buildings, economical impact; “indirect damage”: social impact; “immaterial damage”: psychological impact, etc.

Damage scenario – Geographical distribution of damage for a given earthquake event or a set of events.

Risk – The convolution of hazard with vulnerability for a group of structures, a region, etc. This means the product of probability of occurrence of a certain level of ground motion by the vulnerability of a group of structures, multiplied by their number, and extended to all possible levels of ground motion.

Zonation. Microzonation – Identification of geographical areas having homogeneous similar behaviour under seismic action. Depending on the scale of work, we may consider only the regional differences derived from seismic sources and path, as the case of a gross scale, or consider site effects if working at a detail scale. Microzoning may include also other effects beyond the traditional seismic action parameters, such as landslide, liquefaction, etc.

Networks (lifelines) – Systems of transportation (car traffic, water, gas, electricity, communications, etc.) spread in a region, subjected to different levels of ground motion during a given event.

Essential (critical) facilities – Installations or equipment whose performance during an earthquake is decisive under various different functions: to serve in the emergency operation, to avoid leakage of dangerous products, or due to have a large concentration of population. These facilities, due to their importance should be kept functional under severe or extreme conditions, depending on the expected consequences of failure.

Urban system analysis – An integrated system subsuming all possible consequences of the earthquake impact in an urban centre. Direct, indirect, economic, commercial, business, social, etc., consequences of the earthquake are weighted for a global index value.

Performance – The form a system responds to a given earthquake action in terms of measurement of the functions assigned to that system.

Mitigation – Policies for reduction of consequences of earthquake activity within a lifetime period.

Codes – The most practical and efficient form of designing a structure to withstand seismic action, by defining the minimum requirements (compulsory in some societies and recommendations in others) as far as structural performance. Also codes can be extended to urban and land-use definitions as far as types, sizes, etc. of constructions that can be built in face of existing hazards.

Structural reinforcement – The form of mitigation which considers that vulnerable constructions should undergo reinforcement of their structural system in order to decrease that vulnerability. Recent technological advances have enlarged the spectrum of action for better performance, by using base-isolation techniques, damping devices or dynamic control of structures.

Emergency – Set of actions to be launched when the earthquake occurs. These should optimize the time of intervention (rescue, hospital treatment, etc.) in the most efficient way to minimize the suffering of the populations. Emergency to be fully effective at the needed time requires a great deal of preparation in a great variety of fields of human activity. Preparedness means preparation for the intervention.

Alert – Possibility of expecting a certain level of impact in a region hit by an earthquake, preparing the emergency system for action.