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ADVANCED SEISMIC HAZARD ASSESSMENT

G. F. Panza, K.Irikura, M. Kouteva, A. Peresan, Z. Wang, and R. Saragoni

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edited by

G. F. Panza, K.Irikura, M. Kouteva, A. Peresan, Z. Wang, and R. Saragoni

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Issues pertaining to urban risks are a pressing concern for people involved in disasters mitigation. Development of effective mitigation strategies requires sound seismic hazard information that is commonly derived through a seismic hazard assessment (SHA). The purpose of SHA is to provide a scientifically consistent estimate of seismic hazard for engineering design and other considerations. The time is ripe to move beyond the old paradigms of the traditional Probabilistic Seismic Hazard Analysis (PSHA). Although there are many approaches available for SHA, this volume advocates the advanced methods for SHA that utilize up to date earthquake science and basic scientific principles to derive the seismic hazard in terms of a ground motion or related quantity and its occurrence frequency at a site, as well as the associated uncertainty.

The purposes of this volume are to: 1) identify the issues in the current SHAs, 2) facilitate the development of a scientifically consistent approach for SHA and (3) disseminate, both in scientific and in engineering practice societies, advanced reliable tools for independent hazard estimates, like NDSHA (neo-deterministic seismic hazard assessment), which incorporates physically based ground motion models. It provides a fresh approach to seismic hazard analysis.

The volume consists of two parts. The papers published in Part 1 deal with the general issues of SHA methodology review and development, as well as with recent advances in earthquake science that may have relevant implications toward an improved SHA. Part 2 contains SHA advanced case studies on regional, national and metropolitan scales. This volume is addressed to seismologists, engineers and stake-holders, and aims to contribute bridging modern interdisciplinary research and end-users, who have to cope with the problems of the earthquake risk management and natural disasters preparedness.

CONTENT

Introduction

PART 1: SEISMIC HAZARD ASSESSMENT

PART 2: REGIONAL SEISMIC HAZARD AND SEISMIC MICROZONATION CASE STUDIES

Graves R., Jordan T.H., Callaghan S., Deelman E., Field E., Juve G., Kesselman C., Maechling P., Mehta G., Milner K., Okaya D., Small P., Vahi K. CyberShake: A Physics-Based Seismic Hazard Model for Southern California.

Mualchin, L. History of Modern Earthquake Hazard Mapping and Assessment in California Using Deterministic or Scenario Approach.

Parvez I.A., Romanelli F., Panza G. F., Long period ground motion at bedrock level in Delhi city from Himalayan earthquake scenarios.

Vaccari V., Walling M. Y., Mohanty W.K., Nath S. K., Verma A.K., Sengupta A., Panza G.F., Site Specific Modelling of SH and P-SV Waves for Microzonation Study of Kolkata Metropolitan City, India.

Nunziata C., Sacco C., Panza G. F., Modeling of Gground Motion at Napoli for the 1688 Scenario Earthquake.

De Nisco G., Nunziata C., V_S Profiles from Noise Cross Correlation at Local and Small Scale.

Paskaleva I., Kouteva M., Vaccari F., Panza G.F., Some Contributions of the Neo-Deterministic Seismic Hazard Assessment Aproach to the Earthquake Risk Assessment for the City of Sofia.

Indirli M., Razafindrakoto H., Romanelli F., Puglisi C., Lanzoni L., Milani E., Munari M., Apablaza S. Hazard evaluation in Valparaiso: the MAR VASTO Project.

Peresan A., Zuccolo E., Vaccari F., Gorshkov A., Panza G.F., Neo-Deterministic Seismic Hazard and Pattern Recognition Techniques: Time Dependent Scenarios for North-Eastern Italy.

Sekiguchi H., Yoshimi M., Broadband Ground Motion Reconstruction in Kanto Basin due to 1923 Kanto Earthquake.

Matsuzaki S., Pitarka A., Collins N., Graves R., Fukushima Y., A Characteristic Rupture Model for the 2001 Geiyo, Japan Earthquake.

Morikawa N., Senna S., Hayakawa Y., Fujiwara H., Shaking Maps for Scenario Earthquakes by Applying Upgrade-Version of Strong Ground Motion Prediction Method "Recipe".

Sandi H., Borcia I.S., A Summary View of Instrumendal Data on Recent Strong Vrancea Earthquakes and Implications for Seismic Hazard.

Melkumyan M., Assessment of the Seismic Risk in the City of Yerevan and its Mitigation by Application of Innovative Seismic Isolation Technologies.

Xie F., Wang Z., Liu J., Seismic Hazard and Risk Assessments for Beijing-Tianjin-Tangshan, China, Area.

Molchan G., Kronrod T., Panza G.F., Hot-cold spots in Italian Macroseismic Data.

Some of the papers are already available online.

ADVANCED SEISMIC HAZARD ASSESSMENT

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Introduction

Issues pertaining to urban risks are a pressing concern for people involved in disaster mitigation. With the progressing urban sprawl and the emergence of mega-cities around the world, disasters of all kinds become an inevitable consequence of uncontrolled urbanization. Growing environmental and social (purely scientific and practical disaster mitigation and preparedness) concerns, both on the part of decision-makers and public opinion, have brought a new perspective to the perception of hazard assessment as a valid alternative in the long-term (e.g. retrofitting), and an effective complement in short and medium terms, to traditional design procedure of resistant and safe environment. Recent earthquakes, Haiti earthquake of January 12, 2010 and Chile earthquake of February 27, 2010 in particular, exemplify the urgent need for society to develop the effective strategies and policies to reduce seismic risk and to prevent earthquake disasters. Chile and Haiti are both set on active plate boundaries and have a long history of earthquakes. However, the impacts on the two countries were dramatically different. The magnitude M7.1 earthquake in Haiti resulted in a disaster, killing more than 200,000 people, while the magnitude M8.8 earthquake in Chile did not result in a disaster, killing less than 1,000 people, even though the seismic energy released is several hundred times larger. Chile is prepared for earthquakes and has modern seismic design codes for buildings, bridges, and other structures, while Haiti is not prepared and has no seismic consideration for buildings.

The aim of this Volume is to supply multifaceted information on the modern tools for seismic hazard assessment (Seismic Hazard Assessment, SHA), and to make clear the significant difference between hazard and risk, and hazard mitigation and risk reduction. In general, there are many regions where, due to lack of specific instrumentation/equipment and monitoring, very few data is available. Thus it has become necessary to develop tools for SHA, primarily techniques suitable for implementation in both developed and developing countries, and the optimal use of already available and published data and information is a must. The purposes of this Volume are to: 1) identify the issues in the current SHAs, 2) facilitate the development of a scientifically consistent approach for SHA and (3) disseminate, both in scientific and in engineering practice societies, advanced reliable tools for independent hazard estimates, which exploit, as much as possible, the available seismological, geological and geophysical information. We believe that this Topical Issue will reach different end-users - decision makers and stake-holders - and thus it will contribute to the link between the modern interdisciplinary research and the public administration to cope with the problems of the earthquake risk management and natural disasters preparedness.

The world is full of uncertainties, ranging from personal health, financial markets, to natural disasters. Therefore, dealing with uncertainty is a way of life. Risk is an important concept and measurement for dealing with uncertainty in decision-making. Another important concept associated with risk is hazard. Although hazard and risk have often been used interchangeably, they are fundamentally different. In general, hazard describes a natural or man-made phenomenon that could cause harm to society - hazard refers to the probability of exceeding some ground motion with a given exposure of time, while risk describes a probability of structural or equipment failure with potential resultant in casualties, if it is exposed to a hazard. In other words, risk describes a probable outcome from the interaction between a hazard and vulnerability (someone or something that is vulnerable, when it is exposed to a hazard):

$$Risk = Hazard \, \Theta \, Vulnerability \qquad (1)$$

Hazard is quantified by three elements: a level of severity and its temporal and spatial characteristics, while risk is quantified by four elements: a probability, the corresponding level of severity and its temporal and spatial characteristics. Hazards, the natural hazards in particular such as hurricanes, may not be mitigated, but risks can always be reduced. As shown in equation (1), risk can be reduced through either mitigation of hazard or reduction of exposure or both.

Seismic hazard describes a natural phenomenon associated with an earthquake (i.e., fault rupture, ground motion, liquefaction and tsunami) that could cause harm and can be quantified by three parameters: a level of severity (expressed, for example, in terms of Magnitude, M, and/or Peak Ground Acceleration, PGA, and/or Macroseismic Intensity, I) and its occurrence frequency and location, whereas seismic risk describes a probability of harm if someone or something is exposed to a seismic hazard over a certain time at a location. Seismic hazard may or may not be mitigated. For example, tectonic movement cannot be stopped, but liquefaction at a site can be mitigated by engineering measures. Seismic risk can always be reduced through the reduction of exposure even if the seismic hazard cannot be mitigated.

The relationship between seismic hazard and risk is complicated. The overall risk of a building or facility is determined for both the seismic hazard and the probable building performance estimated by the vulnerability function. Further the probability of the structural failure and the geographical distribution of that probability is not necessarily the same as the distribution of the probability of exceeding some ground motion. In order to estimate seismic risk, we have to assume a model (distribution) for the probability of earthquake occurrence in time (either time-independent or time-dependent ones). One commonly used time-independent distribution is the Poisson model. Under the assumption of a Poisson distribution, seismic risk, expressed in terms of a probability p of earthquakes exceeding a specified magnitude (M) in a given exposure time (t) for an area, can be estimated by

$$p = 1 - e^{-t/\tau}, \qquad (2)$$

where τ is the average recurrence interval of an earthquake with magnitude M or greater. Equation 2 provides a quantitative relationship between seismic hazard (i.e., the possible occurrence, within a seismic zone, of an earthquake with magnitude M or greater, having a recurrence interval τ) and risk (a probability that an earthquake with magnitude M or greater could occur in a given exposure time t), under the assumption that earthquakes occur in time following a Poisson distribution. The quantification of seismic hazard in terms of a magnitude and its occurrence frequency (reciprocal of the recurrence interval) is not sufficient for engineers and other practitioners. The desired quantification is represented by the ground motion and its occurrence frequency at a specific site or in an area. **Therefore, the main goal of SHA is to estimate the seismic hazard in terms of a ground motion or other measurement and its occurrence frequency at a site, as well as the associated uncertainty, from the best available earthquake sciences**.

Probabilistic seismic hazard analysis (PSHA - Cornell-McGuire approach) was developed in 1970's with the aim to estimate seismic hazard in terms of a ground motion and its annual probability of exceedance (or return period) at a site. The reasons why PSHA is so appealing and has become the dominant method for seismic hazard and risk assessments throughout the world include its claimed abilities 1) to consider all uncertainties in earthquake source, path, and site conditions and (2) to provide a seismic hazard estimate to satisfy any need or requirement because its end result is a curve that provides a range of hazard (i.e. from 0.0 to 10.0g PGA or even greater…). However, recent studies showed that 1) PSHA is not based on a valid earthquake source model (point source), 2) the mathematical formulation of PSHA is not valid because the ground motion uncertainty was not treated correctly, 3) the annual probability of exceedance (i.e., the dimensionless probability of being exceeded within one year) has been erroneously interpreted and used as the occurrence frequency (i.e., the number of events per unit of time) of a ground motion. In other words, the return period (the reciprocal of the annual probability of exceedance) has been erroneously interpreted and used as the mean (average) time between occurrences of a ground motion. These have led PSHA to become a pure numerical "creation" without any scientific base. For example, PHSA could "extrapolate" ground motion with a return period of 100 million years from a few hundreds years of the available earthquake catalogues.

One of the fallacies from PSHA is the effort to discriminate two kinds of uncertainties, aleatoric and epistemic, in SHA. "Aleatoric" component is the influence of the factors that we openly consider as uncontrollable and treat as random. In the specific problem of ground motion assessment, this component includes all variability that appears when repeated time histories are generated, as required by PHSA, and the dispersion of the resulting parameters is considered. "Epistemic" variability is related to our limited understanding of the physical reality that leads to inadequate modeling. The interpretation of earthquake occurrence as a multivariate stochastic process, with ground motion observations considered as a dependent marked stochastic point process, requires the knowledge of the joint probability distribution of all random variables involved. We do not have sufficient knowledge concerning the real dependency of ground motion at different locations on the state variables of the stochastic process; we may not even know all random variables involved in our stochastic process. The limited knowledge does not allow us to provide a complete description of the stochastic process parameters involved and therefore, we must rely on models associated with a corresponding amount of epistemic uncertainty. Practically, the ground motion measurements reflect the total uncertainty of ground motion characteristics that represents a combination of epistemic uncertainty and postulated inherent variability of the stochastic process. The model of total uncertainty depends on the model used for seismic process (model of stochastic process and model of state parameters explicitly considered in the model). The inherent variability includes not only the variability of attenuation but also the variability in state parameters such as seismic source parameters (e. g. faulting style, fault rupture velocity etc.) and the characteristics of the travel path of seismic waves. With respect to measurements the uncertainty estimate also contains the measurement errors of the state parameters used in the model (e.g. magnitude, distance). Therefore, splitting uncertainty into aleatoric and epistemic parts does not have a practical meaning in modern seismic hazard assessment.

Another commonly used approach for SHA is deterministic seismic hazard analysis (DSHA), in which seismic hazard is defined as the maximum ground motion from a single earthquake or set of earthquakes and it is calculated making use of the available physical knowledge on earthquake sources and wave propagation processes, by means of deterministic models. The biggest criticism to DSHA is that it does not take into account the inherent uncertainties. However, DSHA practically accounts for all the inherent uncertainties explicitly. For example, the maximum credible earthquake (MCE) ground motion is usually taken as the 84th percentile (i.e., the mean value plus one standard deviation) in the distribution of recorded earthquake ground motions. Although DSHA is not a preferred approach, it is widely used in SHA. For example, the design ground motions for buildings and bridges in California and for nuclear power plants in Japan are determined from DSHA. The weakness of DSHA is that the occurrence frequency of the ground motion quite often is not addressed. As discussed earlier, the temporal characteristic of ground motion is an integral part of seismic hazard and must be considered in engineering design and other policy considerations, particularly for seismic risk analysis.

In view of the limited seismological, geological, and geophysical data, of the progress of modern sciences and technologies, and of the increasing exposures, there is an urgent need to develop advanced approaches for seismic hazard assessment, such as a scenario-based neo-deterministic (NDSHA) and other alternatives that utilize seismological, geological, and geophysical data, and the modern sciences and technologies directly. By neo-deterministic we mean scenario based methods for seismic hazard and risk analysis, where attenuation relations and other similarly questionable assumptions about local site responses, all implying some form of physically not sound linear convolution, are not allowed in, but realistic synthetic time series are used to construct earthquake scenarios that are reliable for earthquake engineering purposes. The NDSHA procedure provides strong ground motion parameters based on the seismic wave propagation modelling at different scales - regional, national and metropolitan. The NDSHA allows us to realistically define hazard in scenario-like format accompanied by the determination of advanced hazard indicators as, for instance, damaging potential in terms of energy. The scenario-based methodology relies on observable data and is complemented by physical modelling techniques, which can be submitted to a formalized validation process. The combination of NDSHA and other alternatives is a must to obtain reliable results concerning the safety of our society.

Development of effective mitigation strategies requires sound seismic hazard information that is commonly derived through a seismic hazard assessment (SHA). The purpose of SHA is to provide a scientifically consistent estimate of seismic hazard for engineering design and other considerations. We should move beyond PSHA, because it is based on fundamental flaws and evident errors, and in fact set a number of model-motivated fatal traps, like those that have sprung on residents of Wenchuan and Haiti. The existing practice is the result of widespread ignorance and intolerance to any revision of the "old good paradigms". Although there are many approaches available for SHA, this topical Volume advocates the advanced methods for seismic hazard assessment that utilize up to date earthquake science and basic scientific principles to derive the seismic hazard in terms of a ground motion related quantity and its occurrence frequency at a site, as well as the associated uncertainty. Consequently, three guiding principles, (1) scientific merit and innovation, (2) clarity of expression and concepts, and (3) direct practical application, were applied to guide the review process and decision on accepting or rejecting a manuscript by the editorial board for this topical Volume. The editorial board also made a concert effort to distinguish seismic hazard from seismic risk, because they are two fundamentally different concepts and play different roles in the development of mitigation strategy and policy.

This volume is not just limited to papers that support the use of the NDSHA approach, but it also contains papers with a critically constructive attitude toward available methodologies (both probabilistic and deterministic) and proposing innovative advanced solutions. Total of 43 manuscripts were received, and 33 of them were accepted. The accepted manuscripts can be divided into three categories of SHA: 1) methodology review and development, 2) case histories, and 3) the related earthquake sciences. Part 1 of the Volume is devoted to the general issues about the SHA and Part 2 contains SHA case studies on regional, national and metropolitan scales.

PART 1

Deterministic seismic hazard analysis and probabilistic seismic hazard analysis (i.e. the so-called Cornell-McGuire approach) are two commonly used methods in seismic hazard assessment. The factors that influence the choice of the seismic hazard assessment procedure, probabilistic or deterministic, still remain open questions and are intensively debated within the scientific community. The debate concerns mainly (a) the decision to be made (i.e. the purpose of the hazard or risk assessment), (b) the seismic environment (whether the study area is in a high, moderate, or low seismic risk region), (c) the available input data and the scope of the assessment (whether one is assessing a site risk, a multi-site risk, or risk to a region). The evolving situation makes it compulsory that any national or international regulation is open to accommodate the most important new results, as they are produced and validated by the scientific community. A recent example is the current Seismic Code enforced in Italy by Ordinance of the Prime Minister (OPCM) n. 3274/2003, followed by others containing amendments and additions: in the Ordinance it is explicitly stated that rules of the code must be revised as new scientific achievements are consolidated. Destruction and casualties caused by the L'Aquila earthquake (6 April 2009; M6.3), despite it took place in a well know seismic territory of the Italian peninsula, is just a sad reminder that significant methodological improvements are badly needed toward a reliable assessment of ground shaking and engineering implementation.

Part 1 of the Volume is devoted to the general issues of SHA methodology review and development, as well as to recent advances in earthquake science that may have relevant implications toward an improved SHA.

Seismic hazard assessment is an effort to quantify seismic hazard and its associated uncertainty. As the same for any natural and man-made event, such as hurricane and terror attack, earthquake has a unique position in time and space. In other words, how to quantify the temporal and spatial characteristics of seismic hazard is the core of a seismic hazard assessment. Detailed discussion on the SHA issues and alternatives is provided by *Wang*.

The general issue of uncertainty analysis and the role of expert judgment in seismic hazard assessment are discussed in detail by *Klügel*, with special emphasis on PSHA methods. In a second paper, Klügel outlines the practical problems, which are typically encountered at the interface between seismic hazard analysis and risk assessment of critical infrastructures. The application of a probabilistic scenario-based approach for the probabilistic risk-assessment of a nuclear power plant is described. Klügel addresses the key issues with respect to the development of a reliable seismic design basis for civil buildings and industrial infrastructures, uncertainty analysis and expert judgment in seismic hazard analysis.

A comparison between the Neo-deterministic (NDSHA) and probabilistic (PSHA) seismic hazard assessments over the Italian territory is supplied by *Zuccolo, Vaccari, Peresan and Panza*. The observed differences suggest the adoption of a flexible and physically sound NDSHA approach to overcome the proven shortcomings of PSHA, thus allowing for a reliable seismic hazard estimation, especially for those areas characterized by a prolonged quiescence, i.e. in tectonically active sites where only moderate size events took place in historical times.

An important contribution and a validated recipe for predicting strong motion from crustal earthquake scenarios, which has been developed to characterize the source model for future large earthquakes, is supplied by *Irikura and Miyake*.

Asano and Iwata also contribute to the characterization of strong motion prediction of inland crustal earthquakes through the characterization of the stress drop on asperity estimated from heterogeneous kinematics slip model based on the data, available from dense strong motion observation network. In a further paper, *Iwata and Asano*, by considering the recent large intra-slab earthquakes that occurred in Japan in 1993, 2001 and 2003, discuss the characterization of heterogeneous source model of these earthquakes toward strong ground motion prediction.

The results of the identification of earthquake asperities along the Chilean subduction zone, using strong motion, are reported by *Ruiz, Kausel, Campos, Saragoni and*

Madariaga. This method has been also successfully applied to the accelerograms of the recent Chile (February 27 2010) Mw=8.8 earthquake, which are the only accelerograms available in the world for an earthquake of such magnitude.

A technique for the evaluation of variation in the predicted ground motions oriented to SHA is proposed by *Yamada, Senna and Fujiwara*, including estimates of the variation of the predicted peak ground velocities and acceleration values, and response spectra at a specific.

Gusev supplies an advanced technique of stochastic earthquake source specification for deterministic seismic hazard assessment, which considers the earthquake source processes and the seismic wave medium response due the earthquake excitation.

It is an acquired result that, in order to provide a realistic earthquake hazard assessment and a reliable estimation of the ground motion response to an earthquake, three-dimensional velocity models have to be considered. Accordingly, some general consideration and validation of a three-dimensional modal summation method are supplied by *La Mura, Yanovskaya, Romanelli and Panza*.

The need for a considerable improvement of the presently popular methods, based on PSHA, for the seismic classification of territory is becoming more and more evident to seismic engineers. Similar remarks also apply to the methods usually adopted for evaluating the amplification of seismic motion with respect to that of the bedrock, as well as the near-fault effects. The limits of the aforesaid traditional probabilistic methods have been stressed by the fact that several violent earthquakes in recent years were considerably under estimated by seismic classifications based on PSHA; the Wenchuan earthquake of May 12, 2008 and the Haiti earthquake of January 12, 2010 are just two recent proofs. Estimates of seismic input based on PSHA turn out unsatisfactory for structures having useful life longer than the usual 50 years; this is the case, in particular, of cultural heritage. The paper by *Martelli* is a contribution to the reliable retrofit of structures with long exposure, as important structures and facilities and cultural heritage.

Research on performance-based seismic engineering poses many challenges, among them the need for a reliable procedure to predict structural damage and collapse as a function of the earthquake ground motion intensity. Energy-based methodology, beyond the potentiality of designing earthquake-resistant structures by balancing energy demands and supplies, allows the proper characterization of the different types of time histories (impulsive, periodic, with long-duration pulses, etc.) which may correspond to an earthquake ground shaking, considering the dynamic response of a structure simultaneously. *Mollaioli, Bruno, Decanini and Saragoni* discuss the correlations between damage measures and energy-demand parameters for performance-based seismic engineering.

The accumulated experience evidences significant shortcomings of macroseismic intensity scales of traditional type and shows that main shortcoming is represented by the total lack of concern for the spectral contents of ground motion. Basic discussion of intensity spectra versus response spectra and some applications are supplied by *Sandi* and *Borcia*.

In spite of the great social and scientific interest, the prediction of return period of the characteristic event for a seismic source zone is still not solved unequivocally. In the same time there are many different methods used in seismology to give a statistical tool for the seismic risk assessment, results of which are often questionable. Some ideas on how the strain rates can be used for this purpose are proposed by *Varga*.

The issues related with the estimation of earthquake recurrence and the frequency-magnitude relationship are discussed by *Nekrasova, Kossobokov, Peresan, Aoudia and Panza*, who illustrate the results of a multiscale application of the unified scaling law for earthquakes. Maps based on different time and location scales are compared between each other. The degree of underestimation by traditional methods of seismic risk at a city is illustrated by providing estimates of hazard and related personal hazard in the major cities of Central Mediterranean and Alpine region.

The characterization of temporal properties of earthquake occurrence, necessary for time-dependent seismic hazard assessment, bridges SHA research and earthquake prediction studies. In his paper, *Bormann* introduces the terms and classifications common in earthquake prediction research and applications, and provides short reviews of major earthquake prediction programs that have been initiated after World War II in several countries such as the former USSR, China, Japan, the United States as well as in several European countries. Future research perspectives, as well as the feasibility and possible problems encountered with the implementation of operational earthquake predictions are sketched.

PART 2

The papers published in this volume, provide advanced **SHA case studies** concerning regional national and metropolitan estimates for different parts of the world, including Asia, Europe, North and South America.

A major limitation of the probabilistic theory of risk itself is that this theory has to reduce risk to the probability of exceedance of only one random variable, since it is not able to consider simultaneously the probability of exceedance of the joint probability of two of more random variables, e.g. PGA, duration and frequency content of an earthquake record. Traditionally, the PSHA uses PGA as the unique random variable. It is disputable how reliable is the PGA as ground motion parameter for realistic description of the ground motion damage capacity, since PGA is not really correlated with the observed damage (e.g. the recently recorded high PGA in Japan in 2008 at the occurrence of the quakes of June 14, 2008, M = 7.2, PGA = 3.8 g and July 24, 2008, M = 6.8, PGA = 1.0 g). The heuristic limitations are another major limit of PHSA - the available short earthquake catalogues worldwide do not allow the statistics inference theory to project the probabilistic estimation for long period of time as 1000-10000 years. To overcome such shortcomings, new ideas about PSHA are proposed by *Graves, Jordan, Callaghan, Deelman, Field, Juve, Kesselman, Maechling, Mehta , Milner, Okaya, Small and Vahi*, such as the CyberShake program: A Physics-Based Seismic Hazard Model for Southern California.

Besides up to date PSHA methods, the results from application of NDSHA approach, aimed at seismic hazard assessment at the urban scale, are illustrated for different cities worldwide. Applying the NDSHA procedure *Parvez, Romanelli and Panza* computed bedrock signals in the city of Delhi, India, considering different scenario earthquakes. Results of Site Specific Modelling of SH and P-SV Waves for Microzonation Study of Kolkata Metropolitan City, India, considering the 1964 Calcutta earthquake, is supplied by *Vaccari, Walling, Mohanty, Nath, Verma, Sengupta and Panza*. The modeling of the ground motion at the historical centre of Napoli, with respect to the 1688 scenario earthquake, was carried out by *Nunziata, Sacco and Panza* applying a neo-deterministic approach. For the city of Napoli, *De Nisco and Nunziata* report their recent results regarding the performed investigations on the construction of Vs profiles, using noise cross-correlation at local and regional scales. *Paskaleva, Kouteva, Vaccari and Panza* supply some estimates of the local earthquake damage capacity for the city of Sofia, applying NDSHA procedure for computation of the synthetic strong motion database.

Indirli, Razafindrakoto, Romanelli, Puglisi, Lanzoni, Milani, Munari and Apablaza report some highlights of the MAR VASTO Project on the Hazard evaluation in Valparaiso.

An integrated neo-deterministic approach to seismic hazard assessment is applied to the Italian territory by *Peresan, Zuccolo, Vaccari, Gorshkov and Panza*. In this study different pattern recognition techniques, designed for the space-time identification of impending strong earthquakes, are combined with algorithms for the realistic modelling of seismic ground motion. The integrated procedure allows for a time-dependent definition of the seismic input, through the routine updating of earthquake predictions, thus providing a useful tool for timely preparedness and mitigation actions.

Important results from modelling and ground motion prediction provide new insights on SHA in Japan. Namely, *Sekiguchi and Yoshimi* discuss the outcomes from broadband ground motion reconstruction in Kanto Basin, due to the 1923 Kanto earthquake. *Matsuzaki, Pitarka, Collins, Graves and Fukushima* report a characteristic rupture model for the 2001 Geiyo, Japan earthquake. *Morikawa, Senna, Hayakawa and Fujiwara* supply results on the recent update and application of the strong ground motion prediction method "Recipe", illustrating simulations of strong ground motions associated with the Mw=6.6 earthquake, which occurred in 2005 in northern Kyushu, Japan. The authors also supply the distribution of seismic intensities and waveforms by using an equivalent linear method for the central area of Fukuoka city.

The intermediate-depth Vrancea earthquake sources represent a regional danger of practical and scientific interest due to their social and economic impact on the territory of the adjacent countries. *Sandi and Borcia* supply an overview of the instrumental data of recent strong Vrancea earthquakes and their implication for SHA.

Some results concerning the assessment of the seismic risk of destruction of the existing building stock in the City of Yerevan and innovative seismic isolation technologies for retrofitting of existing and construction of new buildings proposed, developed and implemented in Armenia and extended to Russia, Romania and Nagorni Karabakh are reported by *Melkumyan*.

Important information toward reliable SHA can be gathered by the advanced analysis of long-term macroseismic observations. Seismic hazard and risk in Beijing-Tianjin-Tangshan, China, area are estimated from 500-year intensity data by *Xie, Wang and Liu* and the major advantages of seismic hazard and risk assessments from the intensity records and site-effects are discussed. Hot / cold spots in the Italian macroseismic data are also discussed by *Molchan, Kronrod and Panza*.

A sizeable part of work on developing advanced innovative tool for SHA has been carried on and supported by ICTP-SAND group, in the last decade. We would like to express our particular thanks to the Abdus Salam International Centre for Theoretical

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