Report on 2nd International Symposium on "Advances in Earthquake Science" (AES-2013) and International School on "Use of e-infrastructures for Advanced Seismic Hazard Assessment in Indian Subcontinent" –

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An International Symposium on "Advances in Earthquake Science (AES-2013)" was held during February 1-2, 2013 at Institute of Seismological Research, Gandhinagar followed by the International School on "Use of e-infrastructures for advanced seismic hazard assessment in Indian Subcontinent" during February 4-7, 2013.

The Symposium was sponsored by Ministry of Earth Science and Nuclear Power Corporation and was organized to take stock of research in India in the field of seismology and plan future research directions and to promote exchange of ideas amongst the seismologists, geologists, earthquake engineers and geotechnical engineers. Eight foreign delegates from Italy, Germany and Taiwan and 150 Indian delegates participated. Over 80 oral and 20 poster papers were presented. Cutting edge state of the art lectures were by experienced scientists and new research by young scientists. Details of different sessions are given below.

Earthquake Precursors and Prediction Studies (Convener: B.R. Arora, UCOST, Dehradun):

Recognizing that earthquake precursory research hold key to earthquake prediction, search for precursors and their documentation has continued in different parts of the globe. Accumulated evidences bring forth variety of precursory signals including seismological, atmospheric/ionospheric, geodetic/geomagnetic, electrical resistivity/ hydrological as well as geochemical anomalies. Despite some definite success, scepticism prevails as noted changes are not observed at all earthquakes sites or even for different earthquakes in the same region. The dilatancy-diffusion model based on behaviour of rocks under stresses in laboratory conditions has some success in explaining some of the noted precursory signals. Induction of concurrent multi-sensor measurements and availability of satellite data have begun to demonstrate the promising role of non-seismological parameters in earthquake forecasting programs. Papers in the session reviewed the advances in earthquake precursory programs and devised road map for future planning and practical application of earthquake precursory research. Papers dealing with several aspects of earthquake precursory research were presented and focused on modern mathematical tools to isolate precursory signature in real time, establishing their space-time relation to earthquake cycle and highlighting strategies for integrating multi-sensor data.

Seismic /Tsunami Hazard Assessment (Convener: A. Peresan, Trieste, Italy)

Purpose of the seismic hazard assessment (SHA) is to provide a scientifically consistent estimate of seismic hazard for engineering design and other considerations. Session included papers on the advanced methods for seismic hazard assessment and seismic microzonation utilizing up-to-date earthquake science 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 Italian scientists presented three papers on Neo-Deterministic methodology and results.

A. Peresan remarked that regarding Hazard Studies and Engg. Seismology, amazing amount of data of high quality has been generated by ISR and different types of analysis have been carried out. India is a good place to carry out new research and check/validate new models. I am going back with positive feeling.

East coast of India is affected by tsunami generated along Andaman-Sumatra subduction zone and west coast from Makran subduction zone. Numerical modelling to determine the tsunami propagation, potential run-ups and inundation from tsunamigenic sources is recognized as useful and important tool, since data from past tsunami are usually insufficient to plan future disaster mitigation and management planes. Models can be initialized with potential worst case scenarios for the tsunami sources or for the waves just offshore to determine corresponding impact on nearby coast. Models can be initialized with smaller sources to understand the severity of the hazard for the less extreme but more frequent events and also for taking into account the shape of the coast line and shelf. Paleo-tsunami study is important to decipher pre-historic tsunamis. All these information then forms the basis for creating tsunami evacuation maps and procedures. Papers were presented on these topics regarding tsunami and seismic hazard assessment studies.

Neotectonics (Convener: V.C. Thakur, WIHG, Dehradun)

Neotectonics is the study of young tectonic events which have occurred or are still occurring in a given region after its orogeny or after its last significant tectonic set-up. The tectonic events are recent enough to permit a detailed analysis by differentiated and specific methods, while their results are directly compatible with seismological observations. This approach has been accepted by many researchers. It is also defined as the study of geologically recent motions of the Earth's crust, particularly those produced by earthquakes, with the goals of understanding the physics of earthquake recurrence, the growth of mountains, and the seismic hazard embodied in these processes. Another source of different interpretations for a region is that changes in different tectonic plates of the region may occur at different times, giving rise to the notion of the "transitional time", during which both palaeotectonic and neotectonic features coexist. For example, for central/northern

Europe, the transitional period stretches from the middle early Miocene to the Miocene-Pliocene boundary. This session included papers on the problems of recent tectonic movements that occurred in the upper part of Tertiary (Neogene) and in the Quaternary, which played an essential role in the origin of the contemporary topography.

Real-time Seismology, Convener: J.R. Kayal, Visiting Professor, ISR, Gandhinagar

Aim of the real-time seismology is to collect and analyze seismological data rapidly during a seismic crisis and utilize them for developing information on hazard, potential damage of large events, actual damage, and aftershock risk, with the aim of mitigating the earthquake impact on human society. Before a main shock the focus is on providing indications for an impending event by time-dependent assessment of hazard and risk. During a shock an alert and shake maps of ground shaking allow rapid assessment of the damage in affected area for relief work; in many cases several seconds to a minute might be available for early warning of strong shaking with options to shut down critical facilities, secure industrial facilities, and issue alarms where appropriate. After the main shock the rapid damage estimates based on seismological information and on a modeled ground conditions can be delivered to the agencies handling emergency. Also, the risks associated with aftershocks can be assessed. Operational systems covering some of the aspects mentioned above are being attempted in the country. Papers were presented dealing with the state-of-the-art of this evolving technology.

J.R. Kayal complimented ISR for organizing the symposium on annual basis and this will help in disseminating new ideas/research and will certainly help young scientists/researchers. The results from Antarctica which were presented in the symposium are fascinating.

Lithospheric Structure (Convener: M. Ravi Kumar NGRI, Hyderabad)

Our understanding of the Earth as a dynamic system has primarily evolved owing to development of new incisive tools to probe the Earth's interior from the crust to core, tremendous strides in acquisition of high quality data from dense observational networks coupled with enhanced computational power. Multi-disciplinary knowledge accrued from high resolution studies of the continental lithosphere, nature and deformation of subducting slabs, physical and thermal state of the mantle transition zone, the lowermost mantle region and the inner core in conjunction with mineral physics experiments is continually refining the forefront of knowledge thereby unveiling the fundamental global and regional scale dynamic processes of our planetary interior. Papers were presented on our current knowledge of the deep structure, evolution and dynamics of the stable continental interiors and actively deforming plate boundary regions in diverse tectonic settings covering research from a wide variety of disciplines from active and passive seismology, geodynamics and Magneto-tellurics. Papers were presented on evolution of the Indian shield and its plate boundary regions like the Himalaya, Burma and Andaman arc.

M. Ravi Kumar remarked that it was heartening to see new and very interesting results being presented by young scientists. Hence, there is hope for future. There was amazing length of discussion after each talk. It necessitated the session chairman to reduce the presentation time and increase the discussion time. The sessions were a learning experience for even senior scientists. He opined that the present research in the field of Crustal Structure is more tool based. It should be more process based. He stressed a need for a regional crustal model of India, as lots of tomographic studies are carried out by various researchers which can be used to develop regional model.

Engineering Seismology: advanced approaches and practical implementation, (Conveners: Antonella Peresan (University of Trieste and ICTP-SAND group, Italy) and Imtiyaz Parvez (CSIR-CMMACS, Bangalore, India).

Lessons learnt from recent destructive earthquakes show that a single hazard map cannot meet all the requirements from different end-users. Nowadays it is recognized by the engineering community that peak ground acceleration (PGA) estimates alone are not sufficient for the adequate design of special buildings and infrastructures, since displacements may play a critical role and the dynamical analysis of the structure response requires reliable time series of ground motion. A reliable characterization of the maximum displacement at different periods is essential, for example, to the design of seismically isolated structures and other special infrastructures. Moreover for structures of considerable linear dimensions (e.g. bridges and also some buildings), it is necessary to account for the possible asynchronous ground motion along the base of the structure.

When dealing with the protection of cultural heritage and critical structures (e.g. nuclear power plants), where it is necessary to cope with hazard for extremely long time intervals, the standard probabilistic approach to seismic hazard assessment (PSHA) is by far unsuitable, due to its basic heuristic limitations. Extrapolating ground motion with an infinitely long return period from a few hundred years of the available earthquake catalogues, in fact, may turn out to be a purely numerical exercise with no connection with reality. Another major problem in classical methods for seismic hazard assessment consisted so far in the adequate characterization of the attenuation models, which may be unable to account for the complexity of the medium and of the seismic sources, and are often weakly constrained by the available observations. The recent introduction of the Next Generation Attenuation (NGA) approach may not be able to remove the problem in that NGA reduces the product of earthquake source tensor with the Green function of the medium, i.e. the tensor product routinely used to formally represent a seismogram, to a scalar (peak value) and such a strong simplification can be totally inadequate, in particular when dealing with the complex geological structures which are present, as a rule, in active deformation areas. Therefore the need for an appropriate estimate of the seismic hazard, capable of properly

accounting for the local amplifications of ground shaking (with respect to bedrock), as well as for the fault properties (e.g. directivity) and the near-fault effects is a pressing concern for seismic engineers. Such problems are expected to be overcome in the Neo-Determisitic modeling proposed by the Italian group. Contributions were on advanced tools for seismic hazard assessment, particularly on the following topics:

- Ground motion modeling
- Site effects characterization
- Source characterization and simulation
- Seismic input definition for special infrastructures
- Interdisciplinary studies about the response of structures to seismic input
- Applications, practical problems and requirements in earthquake engineering

Formation of Working Groups

B.K. Rastogi informed that the delegates have expressed need for forums for frequent in depth discussions and collaboration on various aspects. Therefore it is proposed to form Working Groups on various aspects like Earthquake Precursors, Active Faults, Crustal Deformation, Seismic Microzonation, Seismic Hazard, Earthquake Catalogs and Real-Time Seismology, Networks and Digital Data processing under the aegis of ISES.

Use of e-infrastructures for Advanced Seismic Hazard Assessment in Indian Subcontinent

The International School provided training on advanced tools for seismic hazard estimation. About 40 trainees from different earthquake affected parts of India took part in the International School.

The International School was organized under a project funded by Friuli Venezia Giulia Region Service for International Relations and European Integration with the following partners:

i CSIR–Centre for Mathematical Modeling and Computer Simulation (C-MMACS) [council of Scientific & Industrial Research]
ii International Centre for Theoretical Physics (ICTP)
iii Democritos Modeling Centre for Research in Atomistic Simulation (Democritos)
iv Universita Degli Studi Di Trieste (Department of Mathematics and Geosciences)

Besides the basic lectures on seismology and strong motion processing, the lectures also covered the following topics:

i. Probabilistic and Deterministic methods of seismic hazard analysis and the neo deterministic method devised by the Italian group.
ii Advanced tools of Seismic Hazard Assessment, and
iii Use of Worldwide e-infrastructure for GRID or CLOUD computation for new models enabling more computational power than even a 'Super Computer'. There were more computational exercises with some new Programs developed in Italy.

The faculty consisted of six from Univ. of Trieste, Italy: Ms. Antonella Peresan, Franco Vaccari, Stefano Cozzini, Andrea Magrin, Fabio Romanelli, Francesco De Giorgi and five from India: (i) Imtiaz Parvez of C-MMACS, Bangalore, (ii) ID Gupta, Director CWPRS, Pune, (iii) Prof. J.R. Kayal, (iv) Dr. Sushil Gupta of RMSI and (v) Dr. B.K. Rastogi