Role of Seismic Testing Facilities in Performance-Based Earthquake Engineering

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Role of Seismic Testing Facilities in Performance- Based Earthquake Engineering

SERIES Workshop

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Preface

The Tohoku earthquake that devastated the North-eastern coast of Japan on March 11, 2011 and the smaller, yet also catastrophic, Christchurch (NZ) shock that hit the opposite end of the Pacific Rim less than 3 weeks before, were stark reminders of the weakness of humans and their works against the force of nature. These events came almost exactly 1 year after the extraordinary Bio-Bio earthquake in Chile and less than 2 years after the L'Aquila (IT) earthquake, the strongest and deadliest in Europe for almost 10 years. Within the overall picture of disaster left by these events, one can find bright spots. For example, the performance of buildings and civil infrastructures in the Tohoku earthquake looks like a success story, in view of the magnitude of the shock and of the disastrous effects of the 1995 Great Hanshin earthquake on buildings and civil infrastructures in Kobe. By contrast, the collapse of several RC wall buildings in Viña del Mar and Concepción in Chile shook our confidence to this time-and-again proven type of earthquake resistant construction and our knowledge of it.

In fact, every new earthquake demonstrates many still dark areas and gives the impression, to public and policy makers alike, that our Research and Technological Development (RTD) community of earthquake engineering has achieved little progress in over 40 years of intensive work. We have to bear in mind, though, that, unlike other engineering disciplines, earthquake engineering cannot give RTD answers by testing and qualifying few and small typical components, or even single large prototypes. The extreme diversity of Civil Engineering structures does not allow drawing general conclusions from few tests. Moreover, our structures are large in size and their response and performance under strong earthquakes cannot be meaningfully tested in an ordinary lab or in the field. Testing has to be of large-scale, if possible of real-scale specimens. It often has to be combined with heavy advanced computations, integrated with the large-scale experiments to complement them and extend their scope, even by coupling two different but simultaneous tests. So, nowadays earthquake engineering research infrastructures are much larger and expensive than their counterparts in other fields of Science and Technology. Moreover, their staff have to be very resourceful and imaginative, devising intelligent ways to carry out simultaneously different tests and advanced computations (often at different labs),

in order to draw meaningful conclusions. This means that research infrastructures have to pool their resources and activities and either do their research together or jointly develop advanced testing and instrumentation techniques that will maximize their testing capabilities and increase the output and value of their tests.

Because the US and Japan have the largest overall seismicity among all developed regions of the world, and indeed concentrated mainly in some of their most populous, prosperous and economically important areas, it is natural for them to develop into the two world leaders in earthquake engineering RTD. They have established their leadership by investing heavily in a network of large and expensive, but complementary and well integrated experimental RTD infrastructures.

Europe as a whole has overall seismicity and exposure to earthquakes comparable to that of the US or Japan. Among the about 580 million of the inhabitants of Europe (the present EU, Turkey and the Western Balkans) 41 million (7% of the total) live in high seismicity areas and another 64 million (11% of the total) in moderate seismicity ones. In the last two decades of the twentieth century and in the first one of the 21st, earthquakes caused about 5,300 casualties in the EU (4,800 of them in Italy) and over 19,000 in Turkey alone. The earthquake disasters of 1980 in Irpinia (IT), 1989 in Spitak (Armenia), 1999 in Kocaeli (TR) and Athens (GR), as well as the recent one in L'Aquila (IT), are among the most costly ones in history. The effects of future seismic events in Europe may be even larger, especially in view of the ongoing urbanisation in some of Europe's most seismic areas. To mitigate the overall medium and long term impact of earthquakes, Europe should gradually reduce the seismic vulnerability of its new and existing structures by improving knowledge in earthquake engineering and by disseminating RTD results to its engineering and scientific and technical (S/T) community. This is especially needed in the most seismic but less developed European countries, which also happen to go through an era of frantic construction and infrastructure development.

Nowadays, research in earthquake engineering is mainly experimental and of large-scale. Large, expensive and advanced experimental research infrastructures can only be built by few technologically advanced States (or by supranational entities, such as the European Union). Moreover, the necessary integration and exploitation of such resources can only be done over large geographical areas, e.g., at the European level. The example to follow is that of the "Network for Earthquake Engineering Simulation" (NEES) program of the US National Science Foundation (NSF), which has invested to the present day over \$210 m to upgrade the material infrastructures in 15 earthquake engineering laboratories around the US, couple them electronically via the high performance computational Grid, and directly support access to them by other research teams throughout the US.

In order to be one of the world leaders in earthquake engineering research together with the US and Japan, Europe must transcend the extreme fragmentation of its research infrastructures. EU Member States, Associated and Candidate Countries, being central in the development and financing of infrastructures, have made individually major investments in large and expensive experimental RTD facilities in earthquake engineering: the total present value of investment in material resources in Europe's national earthquake engineering research or university

Institutes is well over €200 m. However, individually these facilities don't have yet the critical mass of people and the broad range of expertise needed for major breakthroughs in the State-of-the-Art of earthquake engineering. Their overall capacity and the associated human resources are used suboptimally, not only owing to fragmentation among different States, but also because they are not open to use by outside researchers even from the same country, let alone from others. Besides, most of the large European seismic research infrastructures are established in few, technologically more advanced but not so seismic EU Member States, while countries with high seismicity have in aggregate fewer and less advanced RTD infrastructures. So, there is a need for better integration of the wider European RTD community in earthquake engineering into the activity of Europe's large experimental infrastructures.

Moving in the direction of integration and of common research infrastructures, the European Commission established in 1992 the European Laboratory for Structural Assessment (ELSA) at the JRC. ELSA is one of the largest research infrastructures of the JRC and has become a world leader in Pseudo-dynamic testing with substructuring for earthquake simulation and a world reference centre for experimental earthquake research. Shaking Table capabilities and Centifuge Test facilities, vital for structural or geotechnical experimental earthquake engineering research, respectively, are also offered in national labs scattered around Europe. In its Seventh Framework Programme [FP7/2007–2013], the European Commission is supporting further integration of all these earthquake research infrastructures through project SERIES (“Seismic Engineering Research Infrastructures for European Synergies”) of its Research Infrastructures Programme (under grant agreement n° 227887).

SERIES's 23-strong consortium comprises the key actors in Europe's seismic engineering research (including 3 industrial firms). Its scope covers all aspects of seismic engineering testing, from eight reaction wall pseudodynamic (PsD) facilities and ten shaking table labs, to EU's unique tester of bearings or isolators, its two major centrifuges and an instrumented site for wave propagation studies. It offers to Europe's S/T community of earthquake engineering Transnational Access to a portfolio of world class seismic research infrastructures: EU's largest PsD facility, four diverse shake tables and the two centrifuges. It fosters co-operation within the wider European S/T community of earthquake engineering, through networking. In Networking Activities SERIES is setting up a public distributed database of past, present and future test results, installs distributed testing capabilities at all PsD labs, fosters development of up-and-coming laboratories at Europe's most seismic regions, drafts and applies protocols for qualification of seismic research infrastructures and engages the entire European community of earthquake engineering via the best possible instances: the European Association of Earthquake Engineering, EU's seismic code makers and their national groups, the European construction industry, as well as all relevant S/T associations or networks. All labs in the SERIES Consortium are also engaged in Joint Research Activities, to explore and prototype novel actuators (combination of electro-dynamic and hydraulic ones) for better control of fast tests or special applications, to advance new sensing and instrumentation systems, data

assimilation in equipment-specimen models for better test control and optimisation of testing campaigns, as well as experimental studies of soil-structure interaction at all types of testing facilities.

The main impact of strong earthquakes that have hit developed countries in recent times was the serious damage to property and the heavy economic losses they inflicted, rather than the casualties. To cover the impact of earthquakes to aspects beyond human life, “Performance-based earthquake engineering” has developed in recent years as the most compelling engineering concept for protection against earthquakes.

“Performance-based engineering” in general focuses on the ends, notably on the ability of the engineered product to fulfil its intended purposes, taking into account the consequences of a failure to meet them. By contrast, conventional structural design is process-oriented: design codes emphasize prescriptive, easy to apply, but opaque rules which are just means to achieve the goal of satisfactory performance, but they don’t describe the goal itself in clear and quantitative terms. Traditional code rules may be convenient for safe-sided, economic solutions under common combinations of design parameters, but leave little room for judgement and creativity and do not provide a rational basis for innovative designs that benefit from recent advances in technology and materials.

The general framework of Performance-based earthquake engineering is now well established. Its objective is to maximize the utility from the use of a structure by minimising its expected total cost over its lifetime, including the expected losses in future earthquakes. As far as development of specific methods and tools, the progress already made is very significant. It has been based so far mainly on numerical and analytical work. It is now high time to put the power and the advanced techniques presently available at large seismic testing facilities to the full service of Performance-based earthquake engineering RTD. Hence, one of the goals of the SERIES project is to promote Performance-based earthquake engineering through its experimental activities. The SERIES Workshop on “Role of Research Infrastructures in Performance-Based Earthquake Engineering” took place in the beautiful and historic Macedonian lake-side town of Ohrid in early September 2010, to serve exactly that purpose. It attracted renowned experts from around the globe who presented about 20 invited contributions, and a fairly large audience.

The Ohrid Workshop and the publication and diffusion of these Proceedings are part of the Networking Activities of the SERIES project and have been made possible through its funding by the European Community.

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