The International Emergency Management Society
2015 Annual Conference, 30th September - 2nd October 2015, Rome, Italy

RELATIONSHIP BETWEEN VISION AND REALITY: ROLE OF SEISMIC SIMULATORS IN PUBLIC PERCEPTION OF SAFETY STRUCTURES

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ABSTRACT :
Physical component of human habitat is represented by the constructions located in various environmental conditions and the earthquakes are often a cause of sudden urban or rural destructuring. In the European Union, the safety of structures to earthquakes is currently provided by Eurocodes and "Performance-based design", but many existing buildings, and even some newly designed, have certain vulnerabilities. Progress-based vision is undermined by the reality of some unexpected disasters (earthquakes L'Aquila 2009, Murcia-Lorca 2011, Emilia Romagna 2012 etc.). In Romania, constructions safety is achieved by adopting a new seismic design Code-P100-1/ 2013, with a new zoning map of the Romanian territory in terms of design ground acceleration values, *ag,* for earthquakes with mean recurrence interval *IMR* = 225 years. With the development of automated computational techniques an illusion is created that, through advanced software, tests on simulators will be replaced. The reality of recent decades indicates that the number of shaking tables has increased, both in the European Union and in Japan, USA, China etc. PEER (USA), NERIES (FP6; 2006-2010) and NERA Projects have shown instead that tests are relevant even at small scale and the sophisticated numerical simulations and calculations are complementary. In construction field, the experimental tests represent a method of investigation absolutely necessary to the development of new products and solutions and to performance evaluation of existing solutions. Also the public perception can be influenced positively by participating in such demonstrations.

KEYWORDS:
Safety structures, seismic simulators

1. INTRODUCTION

Physical component of human habitat is represented by constructions located in various environmental conditions and the earthquakes are often a cause of sudden destructuring urban or rural area. In the European Union, the safety of structures to earthquakes is currently provided by the Eurocodes and the "performance-based design" but many existing buildings, and even some newly designed, have certain vulnerabilities. Vision-based progress is undermined by the reality of unexpected disasters (earthquakes L'Aquila 2009, Murcia- Lorca 2011, Emilia Romagna 2012 etc). In Romania, the safety of structures is achieved by adopting a new seismic design Code- P100-1/2013, with a new zoning map of the Romanian territory in terms of design ground acceleration values, *ag*, for earthquakes with mean recurrence interval *IMR* = 225 years. Specialists and authorities assume that the technical regulations are respected if a system of formal education, training and control have created, but the reality shows that this process is not so easily accomplished. The question of the ways in which we could favorably influence the understanding, perception and implicit the personal and public decision acts on seismic protection is considered [Center, 2009; ROEDUSEIS, 2011; Documentation, 2005; Meita et al, 2011, 2012, 2014; Dobre et al, 2014; Dragomir et al, 2014].

2. ROLE OF PROFESSIONAL AND DEMONSTRATION EXPERIMENTS.

In construction field the experimental tests represent a method of investigation absolutely necessary to the development of new products and solutions and to the performance evaluation of the existing solutions [Meita et al, 2013]. Thus, since the 60s, using "vibrating platform" or "seismic platform" (hereinafter referred to as seismic simulators), the loading of models of structures or equipments, from the natural scale to 1: 6 or 1: 40 was permitted. Seismic simulator is an experimental device and consists of a platform driven by some hydraulic actuators, which can induce a movement similar to that seen during an earthquake to evaluate the performance and the durability of columns, beams, structural and nonstructural components and other characteristics of other substructures of buildings, bridges, dams and civil structures (such as models of these structures) under seismic loading. The platform allows testing an experimental model of the structure or structural components and equipment. There is a wide variety of such devices, they differ in physical size and number of degrees of freedom (1 to 6) to be imposed displacements/rotations, with loading capacities uniaxial, biaxial and multiaxial and who can work alone or can be combined in order to evaluate patterns in a larger size. In terms of structure-model, the theoretical or experimental evaluation of the seismic performance of buildings requires a structural model based on the concept of structural similarity and/or similarity. In general, between a real building and the building model must be geometric, kinematics and dynamics similarity.

2.1. Seismic simulators for experimental testing

Nationally, at the the National Research &Development Institute for Building, Urban Planning and Sustainable Spatial Development (INCD URBAN-INCERC), Iasi Branch, there are two seismic simulators (140 t and 15 t) which allow dynamic testing of structure models, Fig. 1, 2. Seismic simulator with the capacity 140 t and 10m x 10m sizes; movement amplitude ± 13 cm; working frequency range 0.5 ÷ 20.0 Hz; horizontal uniaxial; peak acceleration (in g) 0.6g; maximum velocity 80cm/s etc.; works on the principle of electro-hydraulic system. Pre-recorded acceleration on magnetic tape is reproduced by a dynamic jack that pushes the shaking table unidirectional with alternating horizontal motion. The energy level of the shaking motion is monitored by some control accelerometers mounted on the base and the calibration and performance checking is performed before starting the test program. The primary experimental data acquisition related to the control of the shaking table (seismic action) and mechanical behaviour of tested structural system at earthquakes (answer machine) is digitally by recording simultaneously all the measurement points on the computer, from several types of transducers: accelerometers / displacement transducers.

Figure 1 Tests on seismic simulator (140 t) URBAN-INCERC, Iasi Branch

At INCERC Bucharest, in the 60’s ... 80’s, some scale models of structures 1: 4 with an operated vibrator on the top were tested, so through the correlation with the tests in Iasi, new structural solutions have been validated, Fig. 3.

Figure 2 Building of large panels on seismic simulator (15 t) URBAN-INCERC, Iasi Branch

Figure 3 Models of structures subjected to oscillations

Internationally, there is a wide range of solutions of American and Japanese companies, which provide high performance seismic simulators. A major challenge was finding a way to move the vibrant platforms, which in general are driven by hydraulic, but a method that has not a high accuracy. Therefore, there have been used the actuators based on electromagnets. In Europe there are seismic platforms in R. Macedonia, Greece, Italy (JRC Ispra, Naples), Portugal (Lisbon LNEC), France, Russia etc. In the US and Japan there are universities and institutes that have the own significant seismic platforms of reference, Fig. 4, 5, and China has developed in recent years some innovation and technological development platforms, within which are tested the structures models in 1:40 scale, Fig. 6, 7 and 8 [Fukuwa et al, 2008; Tobita et al, 2009; Ichimura et al, 2004].

Figure 4 The US largest "outdoor" shaking table in the world, 2000 t (University of California at San Diego), led by the Romanian Engineer Dan Radulescu; Network for Earthquake Engineering Simulation; The PEER Earthquake Shaking Table

E-Defense NIED Shaking Table, Miki Town, Japan, is a 3D seismic testing platform, 1200 t force capacity - full-scale tests; 20mx15m dimensions; max horizontal acc. - more than 0.9g; max vertical acc. - more than 1.5g; max horizontal velocity - 200 cm/s; max vertical velocity - 70 cm/s; max horizontal displacement +/- 100 cm; max vert. displacement +/- 50 cm etc., Fig. 5.

In the new earthquake engineering hall at IEM Yanjiao, China, there is a double vibrant platform for testing for earthquake a double pile-deck bridge assembly with equipments imported from Italy and a very large centrifuge for geotechnical tests.

Figure 5 E-Defense NIED Shaking Platform, Miki Town, Japan; the actuators

Figure 6 The shaking table in construction at IEM-Yanjiao (left); Models of super-high buildings recently made, scale 1:40, after testing at China Academy of Building Research, Platform Yanjiao (right)

Figure 7 Models of buildings in preparation for testing on shaking table/seismic simulator at China Academy of Building Research (left); model of structure prepared for testing on shaking table(right)

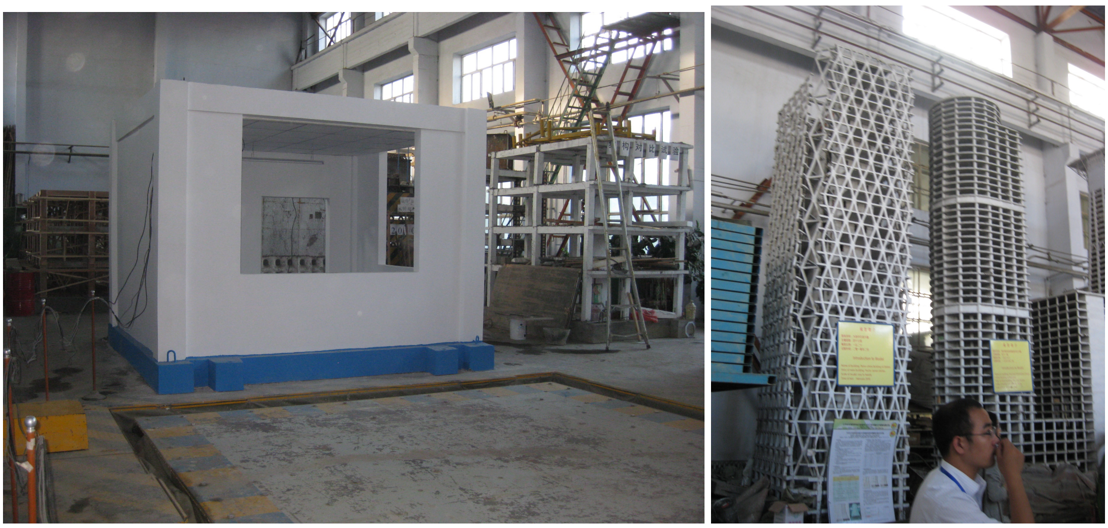

Figure 8 Institute of Engineering Mechanics - IEM Harbin, China. Models prepared for 3 D seismic tests on

seismic simulators/shaking table platform 5m x 5m (left). Models of tall buildings after testing (right)

2.2. Seismic simulators for people, furniture etc.

Apart from pure engineering utility, the main goal of simulation is to train personnel research and intervention, but with free access for students, volunteers and the general public. Due to the precision, the seismic generation mechanism is used in scientific and educational activities on soils patterns/models, structures, equipments. Seismic motions by an intensity of VIII + MM scale can be simulated, based on actual or generated records (artificial accelerograms), being projected simultaneously by video the effects. Motions and effects selection with green/red lights and prerecorded announcements can be combined in many ways, time, content, to create seismic scenarios. The simulator is designed in an independent building, specially constructed and equipped, Fig. 9 ... 11.

Figure 9 – Seismic simulator, Asia-Pacific Network of Centers for Earthquake Engineering Research, Taiwan

The population can experience a default simulated earthquake on a platform arranged to describe a kitchen and, apart from the state felt during the seismic motion, it is possible the self reflexes at earthquake to be tested.

Figure 10 Seismic simulator/"mobile stage" on which a living and kitchen area was decorated, with sound and lights system. "Mobile stage" in motion, a person on the floor protecting the head with the hands, angled shelves, flower pot felled, smoke and video images in motion, Ankara, Turkey

Some examples of simulators created in large projects of some countries from consistently investing in education and training activities of the population are presented.

Figure 11 Mobile seismic simulator during WDRR, Kobe, Japan, 2005 (left). Persons on the platform are subjected to a seismic motion in successive steps. Seated position gives greater stability, so it can reach up to 6 degrees of intensity JMA Japanese Scale (2.5 ... 3.15 m/s^2; 3.15 ... 4.00 m/s^2; for indicative comparison, Vrancea earthquake recording March 4th, 1977 at INCERC reached to 2.07 m/s^2), Japan

2.3. Seismic simulators for educational models of buildings or parts of buildings

Among other awareness activities at the level of exposure to seismic risk, a more practical approach is related to the possibility of presenting realistic scenarios about the behaviour of buildings during an earthquake [Georgescu at al, 2006, 2008; ROEDUSEIS Project, 2011; Tobita et al, 2009; Ichimura et al, 2004; Tataru et al, 2013; Integrated, 2011; Toma et al, 2010; Meita et al, 2012].

With a mini earthquake simulator, which creates two types of motions, high or low frequency, oscillations are applied to simple models of buildings (metal, wood, paper), consisting of a framework/structure with or without structural walls or filling, with or without ground/weak level/flexible floor etc., Fig. 12…18.

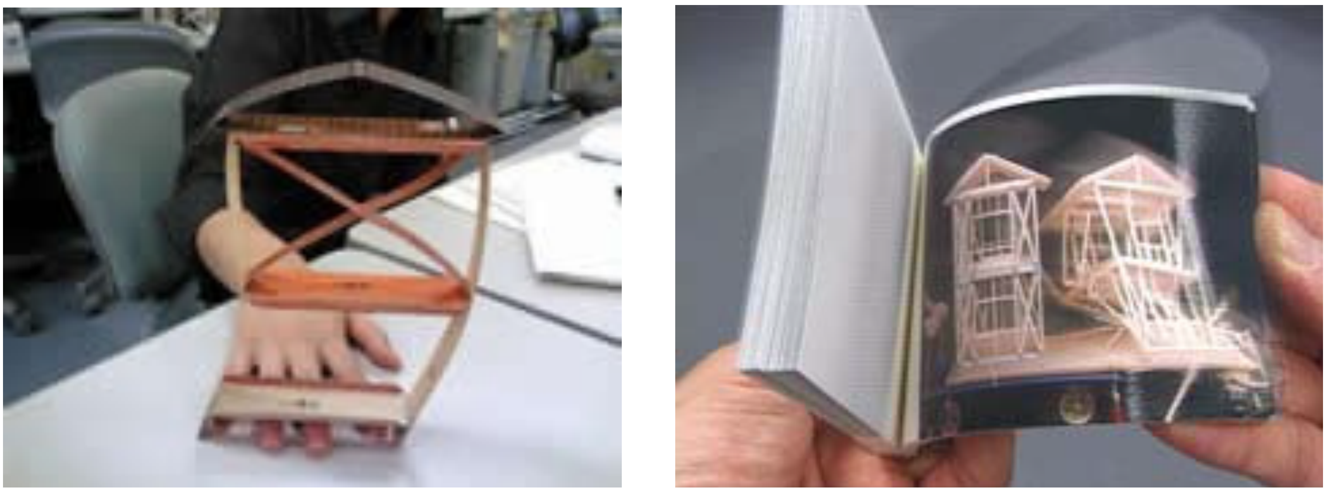

Figure 12 Simple ways of presenting the oscillation of buildings in Japan, by acting on the horizontal arm, and the effects of successive earthquake on wooden buildings; small size card type, consisting of series of images which give the illusion of continuous motion where the pages are turned faster [Fukuwa et al, 2008;Tobita et al, 2009; Ichimura et al, 2004]

"Bururu" Seismic mini-simulators from Japan [Fukuwa et al, 2008] and two models of buildings with different heights and filling walls	The effect of soft ground to a model of higher building with infilling walls at the upper levels	Seismic mini-simulator "Crank-type" - a mechanical process to turn the rotation into forward motion and a model of higher building with infilling walls developed in the ROEDUSEIS Project

Figure 13 Seismic mini-simulators and educational models used in URBAN-INCERC

Fundamental aspects related to oscillations of buildings, their response and damage are demonstrated. Two types of motions correspond to crustal, surface earthquakes, shallow or intermediate depth Vrancea earthquakes, especially in the case of soil foundation from strata consisting of large thickness. The observed effects are related mainly to oscillation mode, the horizontal displacement size, default deformations of real buildings.

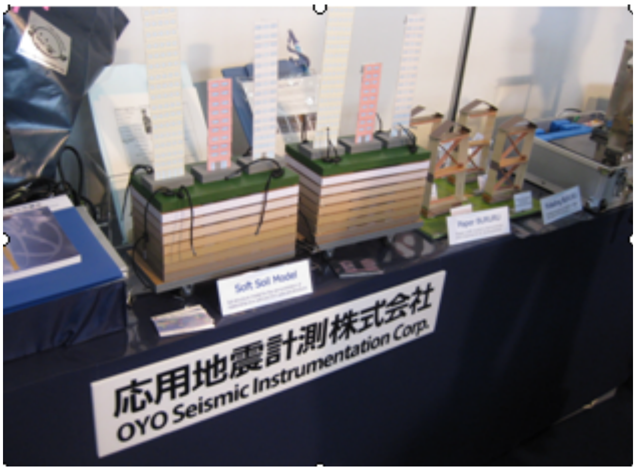

Figure 14 Simple models to understand the influence of foundation soil stratifications on seismic response of buildings, Japan [Tobita et al, 2009; Ichimura et al, 2004]

Fig. 15 UN – WCDR Conference, Kobe, Japan, 2005. Models of stone and earth buildings, with and without perimeter wood belts, used as educational tools in Nepal, subjected to a seismic motion on mini-simulator & patterns of stone and wood buildings, with/without bracings or collar beams

A constant concern to highlight the important role of experimental evaluation using dynamic simulation models and structures in order to obtain a validation of information on earthquake behaviour of buildings, is continued through recent projects, in 2014, and presented at exhibitions and international competitions.

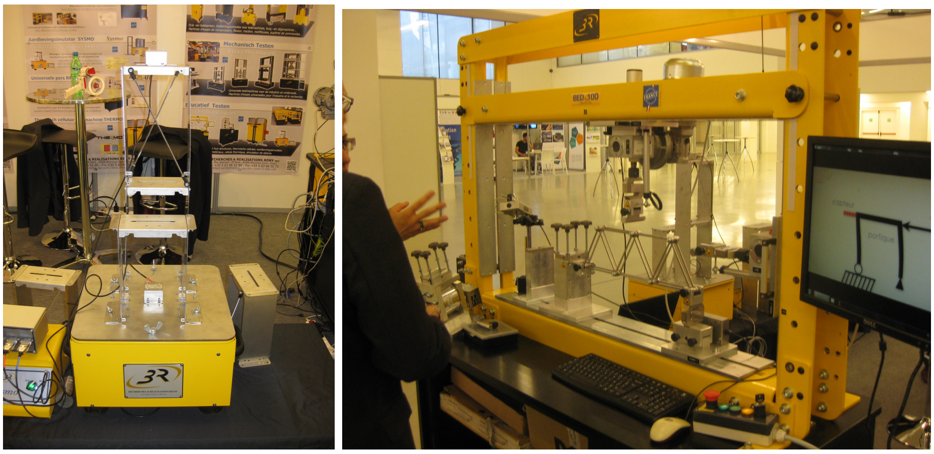

Figure 16 BUILDING TEST EXPO Bruxelles, Belgium, 2014, Educational testing facility for building components, with programs and models.

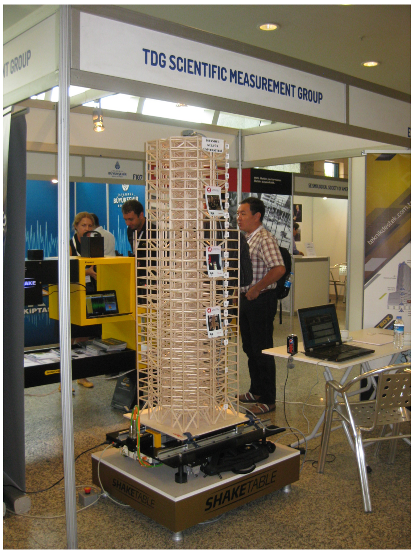

Figure 17 Second European Conference of Earthquake Engineering and Seismology, Istanbul, Turkey, Auguts, 2014. Mini-simulator and wooden structural model

Figure 18 Lightweight building model with controlled seismic performance, elaborated by students from Cluj-Napoca Technical University (First place in the largest international competition dedicated to earthquake-resistant buildings modeled by students, Alaska, USA)

3. RESULTS AND DISCUSSION

Since 1967, INCERC Iasi tests were conducted on a shaking table and the INCERC Bucharest tests were conducted with vibrators mounted on top of the structures, used in both cases on a small scale, but with important conclusions; for instance, the tall high structures from panels were validated and the reaction to the earthquake of 1977 was positive. In 1980's, in INCERC Bucharest and Iasi large investments for seismic shaking tables were initiated (unfortunately unfinished). After 2000, the JICA project shared teaching simulators and since 2009 has been studied in INCERC an arrangement for a Center and demonstration platform for education and training on earthquake behaviour. Recently, in ROEDUSEIS Project (2012-2016), a Seismolab III with JICA and new teaching materials was arranged Fig. 19 [ROEDUSEIS, 2011].

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Figure 19 A Seismolab from URBAN-INCERC within the ROEDUSEIS Project (2012-2016)

4. CONCLUSIONS

With the development of automated computational techniques an illusion is created that, through advanced software, tests on simulators will be replaced. The reality of recent decades indicates that the number of seismic platforms was increased, both in the European Union and in Japan, USA, China etc. PEER (USA), NERIES (FP6; 2006-2010) and NERA Projects have shown instead that tests are relevant even at small scale and the sophisticated numerical simulations and calculations are complementary. Thus, the continuity of seismic simulation demonstrates that, for to check some certain concepts and the structural systems, laboratory work/test is required, of which purpose can exceed the interests of engineering and assuming a specific social role. Public perception can be influenced positively by participating in such demonstrations.

Because earthquake engineering is turning into a complicated mathematical science, physical devices are often necessary to check new solutions, and to draw attention to some typical situations of vulnerability and to convince stakeholders. In many cases, teaching simulators facilitate a culture of disaster prevention in schools or at general public level.

Structural safety can be properly emphasized and perceived through experimental programs involving tests with seismic simulators and by using time-history analysis of specialized software. Seismic simulator makes possible to determine the dynamic characteristics of the structure and their evolution and to check the efficiency of strengthening process of structures. This presentation provides arguments and it is advocating for a revival of the use of these facilities.

ACKNOWLEDGEMENTS

Funding for this research was provided by the Romanian Ministry of National Education-UEFISCDI Agency under the Contract No. 220/2012, Project ROEDUSEIS. This support is gratefully acknowledged.

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