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2nd EFAST Workshop
Reliable Testing of Seismic Performance

EFAST project (Design Study of a European Facility for Advanced Seismic Testing)
Ispra, 29th and 30th of June, 2011

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The EFAST project

EFAST (Design Study of a European Facility for Advanced Seismic Testing) is a joint project financed by the European Commission that consists of a study of all the aspects regarding the design of a major testing facility in Europe that would complement and collaborate with the existing ones. This study aims at identifying the current and future needs in the field, and proposes the concept of a facility using the best available testing technologies (http://efast.eknowrisk.eu/EFAST/).

Objective of the workshop

The new infrastructure could consist of a European class new single-site facility integrated with selected existing ones and, possibly, upgraded to meet new network requirements. During the 2nd EFAST Workshop, 29th and the 30th of June 2011, the project partners presented the preliminary design of the proposed new seismic testing facility as the result of the work conducted during the whole project. Some 30 experts from all over the world contributed with their experience and discussed the most important features of the proposed solution, also taking into account the conclusions coming from the 1st EFAST workshop held in 2009 at the beginning of the project. The objective of the workshop was to allow representatives of the scientific and technical community (such as Universities, Research Centres and Industry) to be aware of the projects findings and to express their interest for such an advanced seismic testing European facility.
In order to increase the visibility of the project toward the above target groups and to promote exchanges between the EFAST partners and the scientific community, the 2nd workshop was held jointly with the 4th AESE conference on Advances in Experimental Structural Engineering (http://elsa.jrc.ec.europa.eu/4AESE) sharing some of the sessions in common.

Organisers

The Workshop was hosted at JRC, Ispra, and jointly organised by the JRC in collaboration with all the partners of EFAST project.

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Program and presentations

The detailed program of the workshop is given in the following two pages. The following link refers to the available slides presented by the invited keynote speakers:
http://efast.eknowrisk.eu/EFAST/index.php/events/2ndworkshop/w2presentations
A brief summary of each talk and the related questions and answers are reported hereafter for each keynote presentation and for the final round table. The final part of this document refers to the conclusions. The 2nd EFAST WS presentations were also attended by the participants to the 4th AESE Conference. However, the final round table was only attended by the officially invited participants of the 2nd EFAST WS. As mentioned above, the objective of the workshop was to inform the members of the scientific community about the outcome of the project and to receive their opinions about the design of the new testing facility coming from the EFAST project and to have their expression of interest. Therefore, the invited participants were representatives of Universities (U), Research Centres (RC) and Industries (I) as can been seen in the list of participants.

2nd EFAST Workshop and 4th International Conference on Advances in Experimental Structural Engineering, *JRC, ELSA, Ispra 29-30 June, 2011*

	OPENING AND KEYNOTE LECTURES - ROOM 11		
9:00-9:15	**Opening:** Stephan Lechner (***IPSC Director***), Artur Pinto (***IPSC, ELSA Unit Head***) Francisco Javier Molina and Paolo Negro (***2nd EFAST Workshop & 4th AESE Conference***)		
9:15-9:40	**Towards a new high performance seismic testing facility in Europe** - *Ioannis Politopoulos*		
9:40-10:05	**Lessons learned from the first 5 years of the NEES network** - *Roberto Leon*		
10:05-10:30	**Seismic Design of Nuclear Installations - Contribution of testing** - *Pierre Sollogoub*		
10:30-10:55	**Interest of seismic tests for administrations and users** - *Helmut Wenzel*		
	COFFE BREAK		
11:25-11:50	**The continuing need for experimental and computational analysis: past, present and future** - *Stephen Mahin*		
11:50-12:15	**The Rules of Structural Model Testing in the Design of Complex Tall Buildings** - *Xilin Lu*		
12:15-12:40	**Numerical seismic analysis of existing structure and SSI using experimental instrumentation** - Stephane Grange and Jacky Mazars		
12:40-13:05	**High bandwidth motion control for seismic testing tables** - *Andrew Plummer*		
	LUNCH AND TECHNICAL VISIT TO THE ELSA LABORATOTY		
	HYBRID AND OTHER ON-LINE TESTING - ROOM1 *Chairman: STOJADINOVIC B.*	**SHAKING TABLE TESTING - ROOM2** *Chairman: REINHORN A.M.*	**IN SITU AND DYNAMIC IDENTIFICATION TESTING - ROOM3** *Chairman: LU W.*
15:15-15:30	**Alternative control strategies in hybrid simulation** *KIM H.K., **STOJADINOVIC B.**, YANG T.Y. and SCHELLENBERG A.*	**Compensation Technique for Simulation of Floor Response Spectra** ***REINHORN A.M.**, RYU K.P., MADDALONI G. and CIMELLARO G. P.*	**Seismic performance of a Multi-tower High-rise Building with Large Podium** ***LU W.**, LU X., and WANG D.*
15:30-15:45	**Hybrid simulation of bridge response under three-dimensional earthquake excitation** ***TERZIC V.** and STOJADINOVIC B.*	**Model-based high- fidelity acceleration control method for shake tables** ***NAKATA N.***	**Experimental testing of a masonry arch bridge model subject to increasing level of damage** *RUOCCI G., DEGIOVANNI L., QUATTRONE A., **ZANOTTI F. L.**, CERAVOLO R. and DE STEFANO A.*
15:45-16:00	**Substructure hybrid test using Model-based Predictor and Corrector Algorithm** ***WANG T.** and CHENG C.*	**Study on the seismic performance of a complex high-rise structure with two towers and lapping transfer columns by shaking table tests** ***WANG B.**, LU X.L., JIANG H.J., LU W.S. and LI J.B.*	**Experimental and Analytical Investigation of Dynamic Characteristics of khorjini Semi-Rigid Connections** ***KAZEM H.**, KAZEM H. and HOSSEINI F.*
16:00-16:15	**Equivalent Force Control Method with Sliding Mode Controller for real-time Substructure Test** ***WU B.**, ZHOU H. and WAGG D.J.*	**Shake Table Test of High-rise Structure with Large Local Space Equipped Torsional Vibration Control Device** ***ZHAO B.**, HE J. and LU X.*	**Experimental and numerical investigation of infill panels effects on mid-rise steel frames** *MIRTAHERI M., **HARIRI ARDEBILI M.A.**, and AGHAGOLI A.*
16:15-16:30	**Collapse simulation of steel structures using Hybrid simulation with innovative substructuring techniques** ***MOSQUEDA G.**, CORTES-DELGADO M. and WANG T.*	**Experimental study on the seismic behavior of a high – rise hybrid structure** ***ZHOU Y.**, LU X. and YU J.*	**Research activities of laboratory for earthquake engineering at national technical university of Athens** ***SPYRAKOS C.***
16:30-16:45	**Real time sub-structuring for soil structure interaction system using shaking tables array** ***TANG Z.**, STOTEN D.P. and LI Z.*	**Response of base isolated building and shake table during moat wall impact experiments** *MASROOR A. and **MOSQUEDA G.***	

THURSDAY – JUNE 30, 2011

	KEYNOTE LECTURES - ROOM 11		
9:00-9:25	**Contribution of various experiments carried out on shaking tables, devoted to the seismic behaviour of reinforced concrete walls, to the evolution of the French code and to Eurocode 8** - *Philippe Bisch*		
9:25-9:50	**Shaking table tests on large scale models of monumental buildings** - *Federico Mazzolani*		
9:50-10:15	**Strategies for Multiple Shake Table Control** - *Patrick Laplace*		
10:15-10:40	**Construction of a multiple shaking-table system** - *Fang Zhong*		
	COFFE BREAK		
11:10-11:35	**Real-time hybrid testing from a general perspective** - *Benson Shing*		
11:35-12:00	**Fast distributed hybrid testing** - *Tony Blackborough*		
12:00-12:25	**Current activities in the George E. Brown Jr., Network for Earthquake Engineering Simulation (NEES) related to research, cyberinfrastructure and education/outreach** - *Julio Ramirez*		
12:25-12:50	**Application of centrifuge testing** - *Alain Pecker*		
	LUNCH		
	CONTROL ERROR ANALYSIS AND COMPENSATION - ROOM1 *Chairman: BURSI O.*	**CYCLIC TESTING OF REINFORCED CONCRETE AND STEEL STRUCTURES - ROOM2** *Chairman: ZANDONINI R.*	**DEVELOPMENT OF EXPERIMENTAL METHODOLOGIES - ROOM3** *Chairman: TSAI K-C.*
14:30-14:45	Novel partitioned time integration methods for real time heterogeneous testing ***BURSI O.S.**, WANG Z., Chuanguo J. and ABBIATI G.*	Seismic behaviour of beam-to-column joints with high strength steel tubular columns *ZANON G., BURSI O., **ZANDONINI R.** and PUCINOTTI R.*	A software framework for Quasi-static structural testing ***WANG K-J.**, and TSAI K-C.*
14:45-15:00	***Real –time hybrid testing with equivalent force control method incorporating Kalman filter*** ***WU B.**, SHI P., SPENCER B.F., PHILLIPS B.M. and CHANG C.M.*	Hybrid control test of connections for buckling restrained braces in RC continuously braced frames ***QU Z.**, MAIDA Y., NONOYAMA M., KISHIKI S., SAKATA H. and WADA A.*	Investigation on the influence of test protocols on performance of Wood frame construction using the Bouc-Wen hysteresis model ***HAIBEI X.**, JIAHUA K. and LU X.*
15:00-15:15	A compensation strategy for a SDOF nonlinear real-time Hybrid testing ***CHEN P-C.** and TSAI K-C.*	Experimental program on design and application of external retrofit walls for low ductility RC frames ***YILMAZ S.**, TAMA Y.S., KAPLAN H., CALISKAN O., and SOLAK A.*	***Experimental study on the mechanical properties of the lining segment joints of a super shield tunnel*** ***LU L.**, LAN X.P. and LIU LH.* **SELECTED RESEARCH RESULTS FROM EFAST PROJECT I - ROOM3** *Chairman: PAVESE A.*
15:15-15:30	Numerical Examination of Substructure Shake Table Tests Including the Dynamics of the Control System ***STEHMAN M.** and NAKATA N.*	The global-local Analysis for a lateral-loading test on a real RC frame Structure ***YUE J.**, QIAN J., LEI T., LU L. and LU X.*	Machine vision system for high precision measurements in dynamic seismic testing *LUNGHI F., **PAVESE A.**, PELOSO S., LANESE I. and SILVESTRI D.*
15:30-15:45	The effect of the delay on real time dynamic substructuring tests in a cable for cable-stayed bridge ***MARSICO M.R.**, LONDONO J.M., NEILD S. and WAGG D.J.*	Investigation of cyclic behavior of composite shear link in eccentrically braced frames (based on experimental and numerical study) ***REZAEIAN A.**, SHAYANFARM And BARKHORDARI M.A.*	Real-time dynamic hybrid test with sub-structuring: theory and step-by-step implementation ***LANESE I.**, PAVESE A. and DACARRO F.*
	COFFE BREAK		
		ENERGY DISSIPATION DEVICES - ROOM2 *Chairman: MAKRIS N.*	**SELECTED RESEARCH RESULTS FROM EFAST PROJECT II - ROOM3** *Chairman: PAVESE A.*
16:15-16:30		In-situ monitoring of fluid dampers for vibration control of structures: experimental investigation *KONSTANTINIDIS D., **MAKRIS N.** and KELLY J.*	Dynamic effects evaluation of soil- foundation interaction for operating advanced testing facility ***ATANASIU G. M.**, QUEVAL J. C., POLITOPOULOS I., MUSAT V. and TEODORU B.*
16:30-16:45		Buckling-restrained Braces Using Steel Mortar Planks; Effects of the clearance between core plate and restraining element on compressive strength ***MIDORIKAWA M.**, IWATA M., SASAKI D., MURAI M. and ASARI T.*	Real-time substructure test of non-linear tuned mass damper using shaking table ***NGUYEN V. T.**, DORKA U., MOHAMMAD K., NASSER, PHAN TRUNG VIEN*
16:45-17:00		Improving Low-cycle Fatigue Performance of a type of Buckling-restrained Braces for Bridge Engineering ***USAMI T.**, WANG C-L. and FUNAYAMA J.*	Using high performance computing in Earthquake Engineering laboratories ***ZAHARIA M.** H. and ATANASIU G. M.*
17:00-17:15		Long-term temperature measurement of rubber bridge bearing exposed to solar radiation for aging estimation ***OHKURA S.**, PARAMASHANTI YK. and ITOH Y.*	Shaking table and hybrid testing modeling ***LE MAOULT A.***
17:15-18:45			**EFAST ROUND TABLE** *Chairman: POLITOPOULOS I.* (only for EFAST Workshop invited experts)

List of participants

Gabriela Maria	Atanasiu	Technical University of Iasi	U
Alvaro	Alonso	ARIES	I
Vincent	Besson	SERVOTEST	I
Philippe	Bisch	IOSIS	I
Tony	Blackborough	University of Oxford	U
Stathis	Bousias	University of Patras	U
Oreste	Bursi	University of Trento	U
Anna	Bosi	JRC-ELSA	RC
Alfredo	Campos Costa	Laboratório Nacional de Engenharia Civil	RC
Chiara	Casarotti	EUCENTRE	RC
Uwe	Dorka	University of Kassel	U
Michail	Fardis	University of Patras	U
Silvia	Giorgetti	JRC-ELSA	RC
Stéphane	Grange	Université Joseph Fourier	U
Igor	Lanese	EUCENTRE	RC
Patrick N.	Laplace	University of Nevada, Reno	U
Alain	Le Maoult	CEA	RC
Roberto	Leon	Georgia Institute of Technology	U
Marco	Livi	Bosch-Rexroth	I
Xilin	Lu	Tongji University	U
Stephen	Mahin	University of California at Berkeley	U
Nikos	Makris	University of Patras	U
Francesco	Marazzi	JRC-ELSA	RC
Federico	Mazzolani	University of Naples	U
Francisco Javier	Molina	JRC-ELSA	RC
Paolo	Negro	JRC-ELSA	RC
Van Thuan	Nguyen	University of Kassel	U
Alberto	Pavese	EUCENTRE	RC
Alain	Pecker	Géodynamique et Structure	I
Pierre	Pegon	JRC-ELSA	RC
Artur	Pinto	JRC-ELSA	RC
Paolo	Pinto	University of Rome	U
Andrew	Plummer	University of Bath	U
Ioannis	Politopoulos	CEA	RC
Jean-Claude	Queval	CEA	RC
Julio	Ramirez	Purdue University	U
Nick	Richardson	SERVOTEST	I
P. Benson	Shing	University of California at San Diego	U

Pierre	Sollogoub	IAEA	RC
Haluk	Sucuoglu	Middle East Technical University	U
Fabio	Taucer	JRC-ELSA	RC
Colin	Taylor	University of Bristol	U
Bradford	Thoen	MTS	I
Keh-Chyuan	Tsai	National Taiwan University	U
Mihai H.	Zaharia	Technical University of Iasi	U
Fang	Zhong	Tongji University	U

Overview of the presentations including questions and answers

29 June 2011 morning

Workshop welcome

Paolo Negro, 4 AESE conference organising committee

Welcoming words summary (no slides)
We have given our best to emulate our predecessors in organising a successful AESE Conference and we hope it to be most successful in combination with the EFAST workshop.

Stephan Lechner, IPSC Director

Welcoming words summary (no slides)
You are at the Joint Research Centre of the European Commission. This conference is very important to contribute to the improvement of the EU standards. An important issue for Europe is to meet the so called 20-20-20 program in cutting the 20% of CO_2 emissions by the 2020 and using the 20% of renewable energy. Our research centre is devoted to give good advice to the EC, each one in its specific sector. We are expected to advice the EC in the field of structural safety and making a way of construction more environmental friendly. We want to make the world safer.

Artur Pinto, IPSC, ELSA Unit Head

Welcoming words summary (no slides)
Just a brief presentation about the ELSA unit, its mission and its activities: SAFECONSTRUCT, PVACS, SERIES and obviously EFAST. We work very intensively in standardisation for construction industry.

Javier Molina, EFAST workshop organising committee

Welcoming words summary (no slides)
2nd EFAST workshop and 4th AESE Conference will reciprocally take advantage of the contemporary presence of the respective attendants to these high level scientific events in experimental engineering.

KEYNOTE LECTURES IN PLENARY SESSION

Towards a New High Performance Seismic Testing Facility in Europe

Ioannis Politopoulos (CEA – France)

Presentation summary

A synthesis of the activities carried out in the framework of the European FP7 project EFAST was presented. The objective of the project was the preliminary design study of a European Facility for Advanced Seismic Testing. To this end the demands for testing necessary to support the modern earthquake engineering research have been investigated and compared to the current capabilities of laboratories in Europe. The performance objectives and requirements were determined.

The proposed experimental facility is composed, mainly, of a high performance shaking tables array and a reaction structure where both traditional (pseudo-static/dynamic) and innovative testing techniques (e.g. real time hybrid testing) can be applied and combined. This new experimental facility will be comparable with important testing installations that are now working or under construction in Japan, U.S.A., China and Taiwan.

Questions

Participant1: How did you evaluate the needs for this new advanced testing facility?

Politopoulos: An exhaustive inquiry was conducted at the very beginning of the project. These data were the base for the discussion during the 1st EFAST workshop where a list of needs was defined. Several reports and papers summarises these outcomes.

Cimellaro: Which is the maximum distance between the two shaking tables?

Politopoulos: The design free clearance between the two tables is 25 meters.

Participant2: Which are the foreseen costs? Who will sponsor the construction and the operation phase? Do you think it will be profitable?

Politopoulos: About the construction costs: they are indicated in the deliverables of the project being around 65 millions of Euro. It is still early to answer the other questions because the project only deals with a preliminary design of the new testing facility. The sponsors, the place of construction, the institution that will run the facility and so on are beyond the aims of the project.

Lessons Learned from the First 5 Years of the NEES

Roberto Leon (Georgia Institute of Technology – U.S.A.)

Presentation

The first five years of the NEES consortium were reported. The initial idea was to establish a national simulation resource for experimentation, computational analysis and performance visualization for the constructed environment under earthquake loading. The objective was to develop underpinning knowledge of the complex response of soils, full-scale structures and other infrastructure systems to support a revolution in earthquake engineering leading to performance-based hazard mitigation and design. To achieve these goals it was necessary transform the research enterprise to broaden participation, foster interactions between researchers and focus on tangible outcomes through use of shared facilities. At the end of the presentation, a summary scorecard was presented (the first one is the judgment in the USA educational system, the second one in the European one):

§ Shared use/ site operations: A+ (8.5)
§ Research transformation: B+ (7.2)
§ Hard technical contributions: B (6.8)
§ Simulation: B+ (7.2)
§ Visualization: C (6.0)
§ Data repository: D- (3.0)
§ Human resources development: A (8.0)
§ International collaborations: A (8.0)
§ Education, outreach and training: C (6.0)
§ Governance: C (6.0)
§ Public relations: C- (5.4)

The NEES data repository was one of the few things that did not work properly, but, as the presentation of prof. Ramirez has shown later, now it is working very well also.

Questions

Participant1: Which kind of problems do you experienced with the NEES database? What was the impact of the use of the database on scientific research?

Leon: The main problem was an initial difficulty in the data extraction. It is difficult to say haw effective was this dissemination policy. The number of scientific papers related to these data is increasing very much, but we will be sure that these data are useful when the experimental results will be included into building codes.

Seismic Design of Nuclear Installations - Contribution of testing

Pierre Sollogoub (IAEA – Austria)

Presentation

The speaker reported his experience coming form his long career and his stay at the IAEA in Austria. New nuclear power plants are now under construction and many will follow in the next years. Due to the Fukushima power plan stations accident, more controls and a better security level is required to the existing nuclear buildings. This leads to a newer impulse for experimental testing of components, piping systems, soil-structure interaction effects, newer study about the rod drop and the fragility of components and structures. The vertical excitation has demonstrated very important for the Fukushima accident and should be studied into details, too.

Questions

Bursi: The piping system must be properly designed for facing earthquakes, but Eurocodes neglect it.
Sollogoub: The section 8.4 deals about this subject. The piping system should be designed for the displacements and not only for the reactions forces.

The Continuing Need for Experimental and Computational Analysis: Past, Present and Future

Stephen Mahin (University of California at Berkeley – U.S.A.)

Presentation

The basic idea is that experiments are necessary because we cannot still rely only on numerical predictions. Numerical analysis is fundamental and has taken advantage for the exponentially growth of the computational power of modern computers. Simulations are more and more predictive because they can be tuned on a large set of experimental data. Nevertheless is important to continue in the experimental activities because several phenomena have still to be fully understood. Moreover the new testing techniques allow tests based on substructuring or hybrid techniques that were impossible during past years. The OpenSees software was presented to better integrated experimental and computational simulation.

Questions

The presentation was very exhaustive and did not leave room for questions.

The Rules of Structural Model Testing in the Design of Complex Tall Buildings

Xilin Lu (Tongji University – China)

Presentation

The new shaking tables array under construction in Tongji University was presented. Different scaling relationship depending to materials and type of structure were faced. In fact, even with very large shaking tables with considerable payloads, very large structures must be tested properly scaled. So, the key technology of the shaking table model test is to find a proper dynamic similitude theory. A methodology for the nonlinear dynamic properties evaluation on scaled models is proposed to solve the strict similitude requirements for shaking table tests. The method provides a solution to reasonably simulate the nonlinear performance of prototype structures using shaking table tests. A design method of scaled RC structures is put forward to consider the similarity of model concrete, reinforcement, bending moment and shearing capacity through designing reinforcement, effective cross section and spacing of stirrups.

Questions

Negro: Is it important to consider the energy dissipation occurring in the small scale specimen compared with the one in the real structure?

Lu: No, it isn't. When you scale a model, you won't get a precise estimation, but you want to get a rough estimation. Eigen frequencies can still be reproduced with much reduced scale models of tall buildings on shaking table. However, nothing can be said about damping or bond.

Participant1: Do you consider the bound concrete elements?

Lu: No, it is impossible, for shaking table testing on bound concrete elements you definitely need large scale specimens.

Numerical Seismic Analysis of Existing Structure and SSI Using Experimental Instrumentation

Stéphane Grange (Université Joseph Fourier – France)

Presentation

To improve the knowledge about seismic modelling, there is the necessity to make confrontations between experimental and numerical results. The cited Arvise project presented two experimental testing campaigns.

The first part of the presentation was devoted with the modal analysis using in situ accelerometers and ambient vibration analysis. These kinds of data can give very accurate and precious information for the understanding of the different components role in the global behaviour of the structure when they are faced with a numerical model. Some non-structural elements, such as the helicoidal stairs for example, had a high sensitivity on the frequencies.

The second part of the presentation proposed the discussion of scaled testing in centrifuge facilities aiming at improving the knowledge at the level of soil-structure interaction (SSI). The confrontation between experimental results and a numerical model allows getting the global parameters (forces and displacements) directly useable for designing foundation and structures. The presented study provides also a good estimation of the impedance coefficient (damping and stiffness) in the time-frequency plane for the specimen and soil considered.

Questions

Participant1: How did you correlate SSI with the obtained experimental data about the tower?

Grange: No, in the tower experiment we didn't consider the SSI because in that case the effect is very low, its foundations are on rocks.

Participant2: Soil radiation in shear boxes is limited. How you can consider it?

Grange: We use a macro-model in the numerical test. Comparing the obtained numerical results with the experimental ones we obtained that in the latter case the radiation damping is bigger.

High Bandwidth Motion Control for Seismic Testing Tables

Andrew Plummer (University of Bath – U.K.)

Presentation

Seismic testing of large structures using shaking tables presents a significant control challenge. Through a detailed case study, some of the problematic dynamic characteristics are highlighted, and the ability of a model-based control method to provide acceptable performance is demonstrated. The process of designing the controller firstly consists of modelling the characteristics of the hydraulic actuation system (valves and actuators), and also the axis interaction in a multi-degree of freedom table. A method for decoupling the control axes is proposed, along with compensation for the hydraulic resonant modes of the table. Experimental results for the case study (a 5m x 5m table) are shown, in terms of frequency responses for horizontal tracking and overturning sensitivity.

When designing a shaking table, please consider the "control bandwidth" rather than the maximum level of acceleration requested because is by far the most important one. Working bandwidth should be defined for EFAST shaking tables. Model-based control allows better accuracy but the specimen must be reliably known.

Questions

Bursi: How do you deal with delay?

Plummer: We do not try to model it; we just consider that there is.

Participant1: What is the key point to wider the bandwidth?

Plummer: Try to compensate the resonance of the oil. This needs very good measurements. We do real-time software compensation.

Bursi: Can you get experimentally the delay function?

Plummer: Yes.

3 March 2009 afternoon

Visit to the IPSC ELSA laboratory

The visit included a presentation given by Javier Molina and Paolo Negro about the testing campaign currently ongoing at ELSA, in particular the SAFECAST and the SERFIN buildings. A guided tour thought the laboratory allowed the visitors to see that structures into details and to further learn about the PsD method used at ELSA.

PARALLEL SESSIONS

The proceedings of the 4th AESE conference have being prepared by the organisers as a separate publication. Hereafter only the parallel session related to the EFAST project is reported.

KEYNOTE LECTURES IN PLENARY SESSION

Contribution of Various Experiments Carried Out on Shaking Tables, Devoted to the Seismic Behaviour of Reinforced Concrete Walls, to the Evolution of the French Code and to Eurocode 8

Philippe Bisch (IOSIS – France)

Presentation

The presentations showed the results of several projects related to reinforced concrete walls performed during the last 20 years in Europe. The relation between the experimental activities and the improvements of the buildings codes suggested that a consistent experimental activity is fundamental for properly understand and model the real behaviour of complex structural elements.

Questions

The presentation was very exhaustive and did not leave room for questions.

Shaking Table Tests on Large Scale Models of Monumental Buildings

Federico Mazzolani (University of Naples – Italy)

Presentation

The FP6 EC PROHITECH research project "Earthquake PROtection of Historical Buildings by Reversible Mixed TECHnologies" (2004-2009) developed a wide experimental and numerical activity on structures, sub-structures, elements and devices. The presentation summarised the main results on large scale models of monumental buildings, which were tested on shaking table for producing damage and then for evaluating the effectiveness of the proposed consolidation systems. In particular, the following monumental tested models were presented:

1) Mustafa Pasha Mosque in Skopje, 1/6 scale model. Strengthening by FRP wraps and FRP rods into mortar joints.
2) the Gothic Cathedral in Fossanova, Italy, 1/5.5 scale model. Strengthening by horizontal and vertical ties.
3) St. Nikola Bizantine Basilica in Psacha, 1/3.5 scale. Base isolation.
4) Greek Temple, Parthenon in Athens, 1/3 scale. Damping connections.

Beside the experimental activity, appropriate numerical models were developed in order to both predict and interpret the testing results.

Questions

Makris: To your experience, which of the 3 presented configurations for columns and architrave is the best resisting scheme against earthquake?
Mazzolani: Gravity stabilise the column.
Makris: This is contra-intuitive because it is common sense that mass will translate into forces during earthquakes.
Mazzolani: You are true, but our studies showed this.
Makris: And what about the rocking and the sliding? They where properly taken into account?
Mazzolani: We construct appropriate models to analyse the structures.
Spirakos: It is always very difficult to extrapolate from the linear behaviour to the non-linear one.

Strategies for Multiple Shake Table Control

Patrick Laplace (University of Nevada at Reno – U.S.A.)

Presentation

An overview of the laboratory at the University of Nevada Reno has been presented. The most representative class tests performed in these last years are described into details with examples. The facility can rely on 3 bi-axial shaking tables that can be moved inside the laboratory to tests different kind of structures as, for examples, curved bridges and bridges with piers subject to asynchronous ground motions. Real time dynamic force control tests can be performed, too. In collaboration with the MTS company they developed a control strategy called: "Specimen Load Dynamic Control". This technique can compensate the resonance of the specimen and is based on the dynamic properties of the specimen to be tested.

Questions

Plummer: In order to use your "Specimen Load Dynamic Control", do you need to perform the calibration tests with the specimen already placed on the shaking table?
Laplace: It is not necessary, it is sufficient to know which are the natural frequencies of the specimen to be tested.
Bursi: Do you think that a model based control could be better than a control strategy that knows nothing about the structure?
Laplace: We plan to try to use the inverse model based control strategy in the future.
Bursi: Your control strategy is good when you have damage also? Do you use a hysteretic model for modelling the damaged structure?
Laplace: Our tests on bridges are all linear because we are presently limited by the calculation power of OpenSees to be performed on-line.

Construction of a Multiple Shaking-Table System

Fang Zhong (Tongji University – China)

Presentation

The presentation dealt with all technical details about the construction of the multiple shaking-table system now in the final phase at Tongji University. All drawing details are shown followed by photos depicting the practical realisation. The 4-shaking table array is a very large structure with impressive amount of construction materials and mans hours works needed to construct it: there are 208 sets of mounting plates, the total number of embedded mechanical parts weights 800 tons (without taking into account the steel bars), the total volume of concrete for the foundation is 11000 cubic meters (i.e. approximate 30000 tons of reaction mass). Nevertheless the construction plane requires a very strict and precise execution in order to allow the movement and replacement of the shaking tables. The plan to put the facility in operation at the end of this solar year should be fulfilled.

Questions

The presentation was very exhaustive and did not leave room for questions.

Real-time hybrid testing from a general perspective

Benson Shing (University of California at San Diego – U.S.A.)

Presentation

The presentation provided an overview of different real-time hybrid testing methods in the context of a unified framework. It has been shown that the pseudodynamic test method with real-time or non-real-time rate of loading, effective force test method, coupled-subdomain method, and dynamic substructuring method can all be represented by the same basic formulation and concept but may differ in terms of the structural partitioning scheme, numerical solution scheme, load application method, and the treatment of the physical substructure. A real-time hybrid testing method using an unconditionally stable numerical integration scheme was described, and methods to assess system performance and to compensate for delays in actuator response were discussed. The feasibility and performance of the real-time hybrid testing method with delay compensation schemes have been demonstrated with proof-of-concept tests conducted on a two-degree-of-freedom structure.

In addition, the presentation showed that the comparison of real and hybrid-test response/excitation transfer function can be used to assess the reliability of the hybrid test. The use of shaking tables tests is also justified by the fact that, when testing buildings with brick infills, there are phenomena in the shaking tables that cannot be reproduced with the PsD method.

Questions

The presentation was very exhaustive and did not leave room for questions.

Real Time Hybrid Testing of Viscous and Visco-Elastic Dampers

Tony Blackborough (University of Oxford – U.K.)

Presentation

The first part of the presentation described the concept of distributed real time testing. The technical challenges to be overcome to perform such kind of tests are discussed alongside with their proposed solutions. Some example of tests showed that they obtained very good results with the proposed techniques. In particular, the feasibility of the proposed solution is shown also for substructures equipped with viscous and visco-elastic dampers. If the found solution is to be more widely adopted, there needs to be a management platform that will define the test: a web based management tool called Celestine is proposed to this purpose.

Questions

The presentation was very exhaustive and did not leave room for questions.

Current Activities in the George E. Brown Jr., Network for Earthquake Engineering Simulation (NEES) Related to Research, Cyberinfrastructure and Education/Outreach

Julio Ramirez (Purdue University – U.S.A.)

Presentation

The George E. Brown, Jr. Network for Earthquake Engineering Simulation (NEES) is a network of 14 advanced experimental sites connected by a state-of-the-art cyberinfrastructure that fosters collaboration in research and education. During the first seven years of research at the NEES experimental sites, over 200 multi-year, multi-investigator projects have been completed or are in progress, yielding many advances in earthquake engineering and a wealth of valuable experimental data. Most importantly, many of the Ph.D. graduate students involved in NEES research, currently hold faculty positions at major research universities worldwide. The results of NEES research are of great interest to the structural engineering profession as they potentially inform and promote code changes as well as advances in design and construction practices. In October 2009, the NEEScomm Center headquarters of NEES Operations was established through a 5-year cooperative agreement between the National Science Foundation (NSF) and Purdue University.

Staff at the NEEScomm Center began then building a new robust and user-requirements driven cyberinfrastructure, NEEShub, on the HUBzero platform, which has proven successful in the area of nanotechnology and several other scientific fields. The NEEShub at www.nees.org released in July 2010, provides convenient access to the NEES data repository (Project Warehouse) and hosts a range of tools for data visualization, analysis, computational simulation and collaboration. The NEESacademy in the NEEShub is designed to host a rich set of resources aimed at disseminating new earthquake engineering knowledge to the profession as well as educating the next generation of researchers and practitioners. In this paper, brief descriptions of the many research, outreach, information technology, and educational activities of NEES are illustrated.

NEES has signed several memorandum of understanding with several countries of the world, including Japan and China, but not yet with Europe. MTS has a global contract with NEES regarding calibration and maintenance.

Questions

Leon: I said yesterday during my presentation that I gave a D minus vote to the database on yesterday's presentation on NEES. I was probably too harsh, that referred to the past, as the database now is not what it was 4 years ago. I agree that now the database shows very good progress and a large number of users and extensive data.

Application of Centrifuge Testing

Alain Pecker (Géodynamique et Structure – France)

Presentation

The presentation provided an overview of the application of centrifuge testing for soil-structure interaction studies. The peculiarity of soil behaviour are illustrated in order to show the increased level of difficulty in matching the scale problems common to structural testing on shaking tables. In order to overcome these problems, there is the need to increase the gravity field. This can be achieved only with centrifugation. So, centrifuge testing is needed and has been developed since many years. Another possibility, obviously, is do not scale the structures and to take a considerable large portion of soil under its foundations, but this require extremely large shaking tables.

Examples of centrifuge testing in practice are: validation of innovative concepts (studies on the foundations of Rion-Antirion bridge in Greece), studies for the obtaining experimental evidence in support of building code requirements (the case of inclined piles in Eurocode 8 is very important) and validation of new tools for nonlinear SSI (the dynamic macroelement showed yesterday by Stephan Grange is a good example).

A distributed test is foreseen with a centrifuge and a shaking table, but the soil behaviour is quasistatic and the test could also be done with the centrifuge and a PsD facility.

Questions

Molina: Could the substructuring methodology with the macro model for soil proposed for shaking tables be used for PsD testing?

Pecker: Yes.

Negro: Using the macro model as proposed by Alain pecker is not possible for coupled problems, such as soil liquefaction.

Pecker: I agreed with the observation made by Paolo Negro.

30 June afternoon

PARALLEL SESSION: SELECTED RESEARCH RESULTS FROM EFAST PROJECT

Machine Vision System for High Precision Measurements in Dynamic Seismic Testing

Alberto Pavese (EUCENTRE – Italy)

Presentation

The presentation provided an overview of the developments that Eucentre has done regarding the use of fast digital camera tracking of prefixed marked points on the tested structure. Several examples were shown where this new technique was usefully applied on in-plane movements. Some undergoing improvements were also described as, for example, the stereoscopic vision of moving points that exhibit both in-plane and out-of-plane movements.

Questions

The presentation was very exhaustive and did not leave room for questions.

Real-Time Dynamic Hybrid Test With Sub-Structuring: Theory and Step by Step Implementation

Igor Lanese (EUCENTRE – Italy)

Presentation

The presentation provided an overview of the development that Eucentre has done regarding the implementation of substructuring techniques for hybrid testing. Some integration schemes suitable for hybrid testing are presented. A comprehensive example of application on a real case is also presented. Eucentre applied the real-time dynamic hybrid testing technique with substructuring they developed to the test of the bearings used during the project C.A.S.E. at L'Aquila. This project led to the construction of several villages of seismically isolated houses in the surroundings of L'Aquila. This choice fastened the construction of new safer buildings after the L'Aquila earthquake of the 6th of April 2009.

Questions

The presentation was very exhaustive and did not leave room for questions.

Dynamic Effects Evaluation of Soil- Foundation Interaction for Operating Advanced Testing Facility

Gabriela Maria Atanasiu (Technical University of Iasi – Romania)

Presentation

The presentation focused on the numerical study that the Technical University of Iasi has performed regarding the dynamic analysis of the soil-foundation interaction for the new foreseen EFAST testing facility. Since the localisation of the new facility is beyond the scopes of the project, a typical soil layout has been taken into consideration.

Questions

The presentation was very exhaustive and did not leave room for questions.

Real-Time Substructure Test of Non-Linear Tuned Mass Damper Using Shaking Table

Van Thuan Nguyen (University of Kassel – Germany)

Presentation

The presentation focused on the experimental testing campaign that has been conducted at the University of Kassel regarding their advancements in substructure testing. After an introduction about the experiences of the University of Kassel in substructuring testing, the test set up and the implemented algorithm are presented. A comprehensive testing campaign was illustrated and the main results were discussed.

Questions

The presentation was very exhaustive and did not leave room for questions.

Using High Performance Computing in Earthquake Engineering Laboratories

Mihai Zaharia (Technical University of Iasi – Romania)

Presentation

The speaker described the main requirements of the new foreseen testing facility in terms of computational power. Some alternative solutions are discussed as, for example, if it is better to have high power computing capabilities inside the new testing facility or, on the contrary, it is more suitable to externalise these services. The author conclusion is that the first option is preferable. The communication needs for telepresence and geographically distributed testing are briefly illustrated, too.

Questions

The presentation was very exhaustive and did not leave room for questions.

Shaking Table and Hybrid Testing Modeling

Alain Le Maoult (CEA – France)

Presentation

The presentation focused on the modelling of the actuators. In order to precisely move the structure is necessary to have an accurate model of the hydraulic actuators. This is a prerequisite to effectively have the capabilities to perform real-time hybrid tests. The actuators are in fact required to move fast and acting with high forces but, in the same time, they must move accurately both in phase and in amplitude. In the opposite case, the test did not reproduce the requested earthquake or excitation pattern. The actuator and servo-valve has been analytically modelled and the involved parameters where identified. The comparison between the obtained analytical model and the experimental measures showed that the model was well tuned. The improved control system was used to perform a hybrid test involving a virtual steel structure equipped with a tuned mass damper. The comparison between the so obtained results with those coming from the test of the real steel structure equipped with the TMD has clearly showed that the goal was accomplished.

Questions

The presentation was very exhaustive and did not leave room for questions.

OVERVIEW OF THE FINAL ROUND TABLE

Chairman: Ioannis Politopoulos (CEA – France), Javier Molina (JRC – EC)

During the round table, amongst others, issues related to the questions presented in the attached slides were discussed.

The elaborated text of the agreed document of the round table is given in the conclusions. Some of the personal comments expressed during the discussion were the following:

Politopoulos: The first proposed theme for discussion is: are movable shaking tables a reasonable choice?
Laplace: Movable tables on a strong floor have the big disadvantage of the lower frequency range, but also the time and cost of movement.
Dorka: Flexible facility idea includes capacity to test a 200 ton building by moving its base directly on the strong floor.
Leon: The idea of movable shaking table is, in principle, good. The proposal should have a component of "sexiness" in order to be attractive.
Politopoulos: Our proposed new facility will have a trench for precise testing and a strong floor for having the needed flexibility.
Zhong & Lu: The choice depends on the sizes of the shaking tables: Big performing shaking tables need a very rigid strong support that cannot be given if they are elevated. Very large movable shaking tables have also the problem to face the very high overturning moment.
Politopoulos: The second proposed theme for discussion is: hybrid testing is, in your opinion, more an exercise for academic researcher or it will have a real practical future?
Bursi: For 1 or 2 actuators RTHT (real-time hybrid testing) can be reliable for testing devices.
Politopoulos: What about the accuracy in velocity and acceleration?
Bursi: MTS has a very good controller, but in any case it depends on the dimensions of the specimen.
Mahin: Facility should include hybrid capabilities for the Shaking Test.
Shing: Current RTHT cannot be used for complicate systems, but will be good for applications with two actuators. It is good, for example for studying various types of dampers, the problem of SSI and so on.
Makris: Do we really need large tests? What are the needs? Sometimes seems that bigger, faster, stronger and larger are the keywords for every test. But do we really need such new testing facilities, or, on the contrary, is it possible that we have to further utilise the means we already have?
Politopoulos: the inquiry we have conducted at the beginning of the project clearly stated that there is room for a new more powerful testing facility. The inquiry and resulted in a paper on an International Journal.
Dorka: The report on testing needs is available on the EFAST web site.
Taylor: There is a need for large scale SSI tests. Objectives and needs change after some time. Flexibility is important.
Leon: Is the facility designed for multi-hazard (e.g. by including also fire and wind). This would allow to cover a larger range of the tests demand.
Tsai: A possible future extension of the facility should be foreseen already in this design phase.
Ramirez: The fact that shaking tables tests are now used for qualification purposes implied a considerable improvement in quality management of such kind of tests. MTS has a global contract with NEES regarding calibration and maintenance that also covers the labs that do not have MTS equipment.
Plummer: Bandwidth and phase degradation will also be affected by having the shake tables in a pit or elevated on a floor. All the boundary conditions affect the control strategy. The requirements should also be very clearly stated, because the dynamics, the requested bandwidth, the needed frequencies all affect the choice for the best control law. The system should allow for openness in the control

algorithms, so it is very strategic to decide if the control system is bought already done and operational or if it is foreseen to develop it “in house”. The second option is surely more difficult and costly, but leaves much more freedom.
Mahin: Shake tables must have always protection against collapse of the specimen, even when the collapse is not foreseen for that earthquake.
Ramirez: In case of accidental collapse, the NEES facility covers with the cost through insurance. These governance rules should be developed at the same time that the facility is designed.
X. Lu: Tongji has insurance for paying accidents, including the cost of the specimen.
Laplace: New needs appear when you have the means. This cannot be seen before.
Bisch: There is still mostly need for testing dynamically medium size systems composed of several elements. Testing of individual, elementary, sub-elements is not enough if we want to understand the response of the whole system/structure.

Conclusions

The discussed matters during the round table were revised during the post-workshop meeting held on the 1st of July 2011 at ELSA laboratory. This meeting was attended by all the partners and prof. Taylor and prof. Fardis of the Scientific Committee. Prof. Mahin attended also the meeting as an external observer since the EFAST partners considered that his large experience on seismic testing could be beneficial for the project. The draft document prepared by the chairmen of the round table held the day before during the 2nd EFAST workshop was analysed and discussed. The participants made suggestions and additions to what was discussed the day before in relation to the final remarks to be taken into account by the future EFAST testing facility.

Politopoulos made a brief overview of the various aspects investigated during the project. In particular, he focused on the general characteristics and lay-out of the facility and presented the proposed solutions and the retained "reference" solution. He pointed out that the three proposals (EUCENTRE, UNIKA and "reference" solution) have some common points. In particular:

- All proposals can be considered as flexible concepts (to different degrees)
- All proposals are compatible with real time hybrid tests combining shake tables and other reaction structures
- All proposals intend to meet the performance requirements (carry out test on relatively heavy models submitted to high intensity records)

He highlighted also that the retained solution combines the advantages of both EUCENTRE and UNIKA solutions with the restriction that, for cost reasons, its dimensions (length of the pit and dimensions of the strong floor) are smaller than those of the other two solutions. In particular the reference solution combines the enhanced accuracy, safety and operational ease of "traditional" tables in a pit of the EUCENTRE solution with the flexibility of a big strong floor, where dedicated set-ups (small shaking tables included) could be mounted on, of the UNIKA solution.
Some other aspects related to technical and non-technical issues were also presented briefly. This presentation served as the basis for an exchange of observations between the participants. Hereafter there are some of the personal comments expressed during the discussion:

Taylor: What is the actual state of the design plans?
Politopoulos: The project aim was to make a preliminary design of the new envisage earthquake seismic facility, not to make a final design. So, we have preliminary reports with the outlines of the testing facilities with specifications and costs, but not construction drawings and detailing plans.
Taylor: How did you identify the needs asking for this new facility?
Politopoulos: We conducted a comprehensive inquire to the main universities, industries and research centres involved in earthquake engineering experimentation. The 1st workshop was also a good occasion to analyze the obtained data with some of the main experts in the word and to better identify the needs. We wrote also some reports and some papers on international journals about this point.
Mahin: Why do you foresee a large shaking table with only 1DOF? Is it a problem of costs?
Politopoulos: Not only for costs reason, but also for control issue. In our proposal we try to make a balance between costs and benefits. We try to go a step further the current capabilities of seismic laboratories in Europe, but we did not want a completely revolutionary solution. We want to remain on something that can be somehow realised, not to speak of dreams.
Pavese: The idea is to have a large SDOF shaking table for geotechnical studies and to have two others smaller shaking tables with multiple DOF that allow advanced research programs. These shaking tables can be moved in the trench and can be coupled, if necessary.
Fardis: Why you limited the trench length to 40 meters?
Politopoulos: We have to end somewhere the trench. We chose that value for cost reason. We need also to know where the crane can move.
Artur Pinto: The three tables are usually simultaneously in the trench?

Politopoulos: No, the SDOF geotechnical shaking table is alternative to the two 3DOF ones.
Artur Pinto: Why do not leave the possibility of make an extension of the trench?
Politopoulos: As I said, for cost reason. Our proposal is already around 65 millions €, it is not reasonable to increase any more the costs.
Politopoulos: There are several places where the new laboratory could be constructed, also Saclay is a good candidate place. This issue will be discussed in a second time, however. For the moment we determined some criteria for the construction site.
Fardis: What about the personnel? Do you have any idea of the required number of people for conducting such a new facility?
Queval: We need 16 people. We need 10 technicians to operate the installation plus 6 other people. These people are at the minimum, just to make the facility running.
Fardis: And what about the "brain"? I mean, you will surely need to have also project leaders, scientific people analysing the data, simulation people etc.
Politopoulos: These considerations are beyond the aims of the project, it depends on who will construct the facility, who will manage it etc.
Pegon: The scope of the project was to estimate the running costs of the facility.
Fardis: The human resources are a cost to be carefully taken into consideration. In my opinion also the scientific staff should be included at this stage. In any case, the chosen solution should be detailed into the deliverable.
Taylor: The different ways of managing the new facility should be taken into consideration during this phase. For example, it will be a private facility or it will be part of research centre or a new institute at national level?
Politopoulos: These administrative issues were not taken into consideration; our study was mainly focused on the technical aspects.
Pavese: If we can take Eucentre as a reference case, I can say that our laboratory involves 30 people. Eucentre is a non profit Foundation launched by the Dipartimento della Protezione Civile, the Istituto Nazionale di Geofisica e Vulcanologia, the Università degli Studi di Pavia and the Istituto Universitario di Studi Superiori di Pavia, with the aim of promoting, sustaining and overseeing training and research in the field of the reduction of seismic risk. I think that the reasonable number of large tests to be performed each year in the foreseen facility is around two. This figure comes from taking into consideration the actual situation in Europe.
Mahin: We do around 40 large tests per year at UCSD, at E-Defence they do 15 large tests per year. Why so few in Europe?
Pavese: More than two companies paying for large tests in Europe is not a real estimation. The experimental costs are very high and only a few companies are able or want to pay for them. On the other site, it is true that some Italian, French and German industries, especially concerned with the nuclear power plant components production, very often go to Japan to test their devices. The idea of the EFAST project was to have an experimental testing facility comparable to the Japanese or American ones.
Artur Pinto: The dismounting and safety costs must be also taken into account. In any case, the scope of being at the same level of Japanese and American laboratory is not enough to justify a new testing facility.
Pavese: I think it is enough: in fact, several Italian, French and German companies construct nuclear power plant equipments for Russian and Canadian.
Taylor: Who wanted E-Defense?
Mahin: The government after the Kobe earthquake in 1995. They put a large amount of money at the beginning. Now the financial support is progressively reducing, but E-Defense has developed a business that can sustain the facility. In any case Japan is a very highly seismic region, this imply that there the research in seismic protection is always on the front hand.
Fardis: They have a public opinion strongly in favour of E-Defense, this makes the difference with Europe.

Molina: At the beginning o the project we identified that a larger shaking table facility was missing in Europe.
Pegon: Which are the actual deficiencies of the current facilities in Europe?
Alberto: We need to run the test up to the collapse. We also need more overturning moment.
Taylor: Which are the kinds of tests that can presently be conducted only at E-Defense?
Mahin: Tests with large laminar boxes, for example. Tests for the nuclear industry, for piping systems, big scale tests in 6 DOF directions can be done only at E-Defense. Moreover, people believe more to large scale facilities tests.
Alberto: At Christchurch earthquake, in New Zealand, the vertical component of the ground motion was very relevant. Nobody has extensively investigated this aspect, for the moment. Also the frequency content is very important.
Artur Pinto: Do you plan to insert this facility in the ESFRI roadmap?
Politopoulos: We have already prepared a report with a preliminary proposal for the ESFRI roadmap, but for the moment there is not any foreseen update of the roadmap.

Acknowledgments

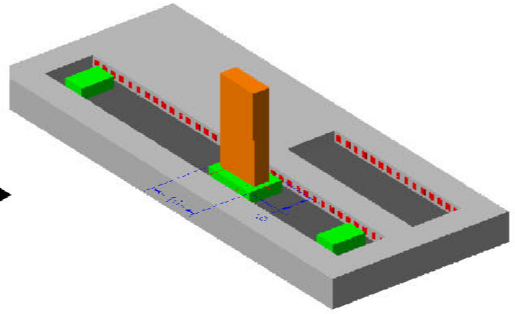
The Authors thank the project partners and the colleagues of the ELSA unit for their help in organising and conducting the workshop. The secretary Claudia Carniel made an enormous logistic and administrative work. Particularly useful for this report were the detailed notes taken during the sessions by our colleagues: Fabio Taucer, Anna Bosi and Acun Bora. Thanks also to Silvia Giorgetti who took in care to collect all the presentation files. Ioannis Politopoulos also revised this document constructively.

Some open questions

- "Completely" movable shake tables vs tables in a pit
- Future evolution of real time substructure testing
- SSI testing. Limitations
- Performance-cost trade-off. EFAST proposal: weak points (or points that could or should be improved)?
- Calibration of measurement instruments and laboratory qualification
- Current accuracy and future evolution of shake tables control
- Feedback from tests up to collapse

Conventional shake tables (in a pit) vs "completely" movable tables

?



Beijing University of Technology
Very flexible but low performances
(1mx1m, 5 t, 0.075m, 1.5g, 0.6m/s)

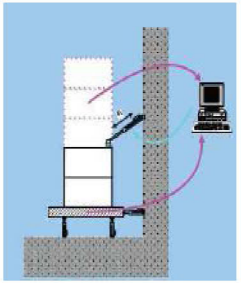
Tongji University
less flexible but higher performances
(3mx6m, 30-70 t, 0.5 m, 1.5 g, 1m/s)

Could movable tables on a strong floor replace conventional tables for medium – large scale tests (without considerable cost increase)?

- Performance (Payload, stroke, 3(6)D)?
- Handling, safety issues? Special scaffold? Time needed for preparing a test?
- Control issues?

Future evolution of Real time hybrid testing

- Most applications deal with “academic examples” unless the physical substructure is a very simple structure (e.g. NL dampers in frame bracings, bridge piers, isolation bearings etc).



- Could the method be applied to more complex physical representative substructures?
  - Can we apply accurately “realistic” boundary conditions (forces + torques or displacements + rotations) to a complex substructure (not merely to a simple substructure like a single column)?
  - Strain rate (and in general velocity) and inertial effects are they represented accurately (imposing “accurately” displacements does not automatically imply that velocity and acceleration are accurate)? If not, what is the interest of real time substructure testing compared to pseudodynamic substructure testing?
  - Accuracy of the method in the case of a stiff physical substructure (influence of response time and time delay)?

Soil-structure interaction

	Scale	mass (t)	dimensions (m)	PTA (g)
SSI: Bridge Pier (1000 t)	1:4	400	7x7x(3+3) L x W x H (1 DOF table)	1.0

- Can we conclude that
  - because of the soil weight, only, simple models can be tested even on a high payload shaking table?
  - it is not possible to meet all similitude requirements (e.g. static stress, energy radiation)?

- Is there an existing or emerging experimental method (in laboratory) for SSI tests with big models?

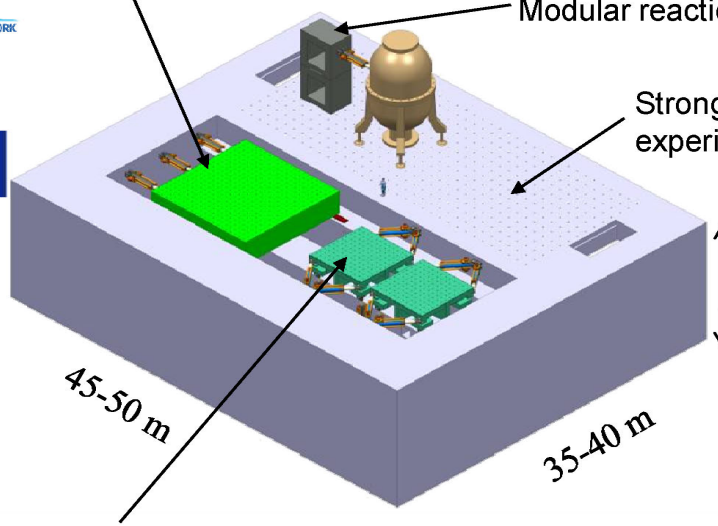
EFAST performance-cost trade-off

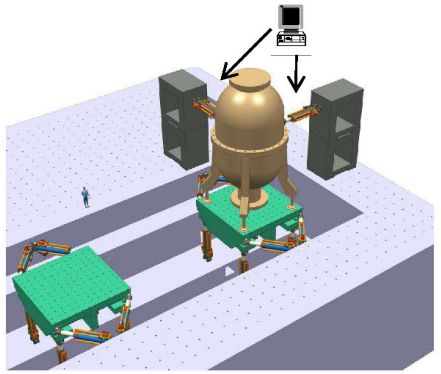
	Soil-Structure Interaction	Tests on civil engineering structures	Secondary structures or equipment
height of specimen:	6 m	10-15 m	**10 m**
mass of specimen:	**400-500 tons** **1DOF**	**200 tons** **2x6DOF (max distance 30 m)**	**1 - 100 tons**
number of directions:	1	1 - 3	1 – 6
displacement:	± 1 m	± 1 m	± 1 m
velocity:	± 2 m/s	± 2 m/s	± 2 m/s
acceleration:	± 1.5 g (0.6 g - 1 g)	± 2 g	± 2 g (100 tons) ± 6-7 g (10 tons)
frequency range:	0 – 50 Hz	0 – 50 Hz	0 – 100 Hz

1 DOF table with high payload (11x11, ≈500t, 0.6-1 g)

Modular reaction wall or frame

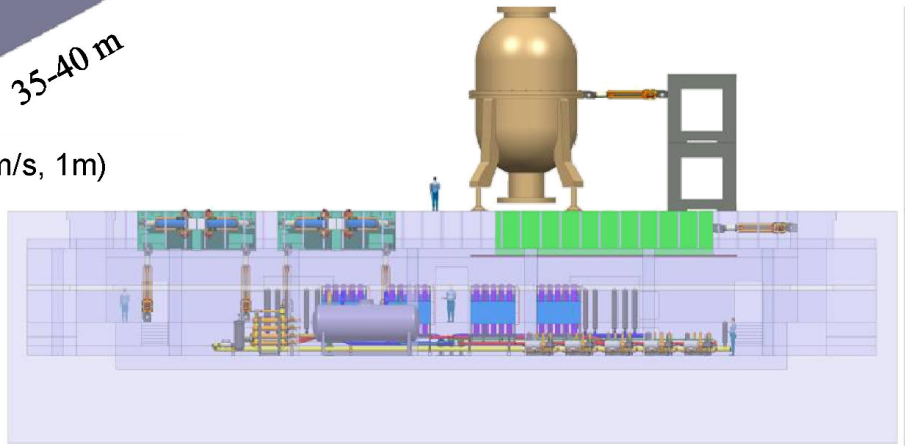
Strong floor for dedicated experimental set ups





Real time hybrid testing

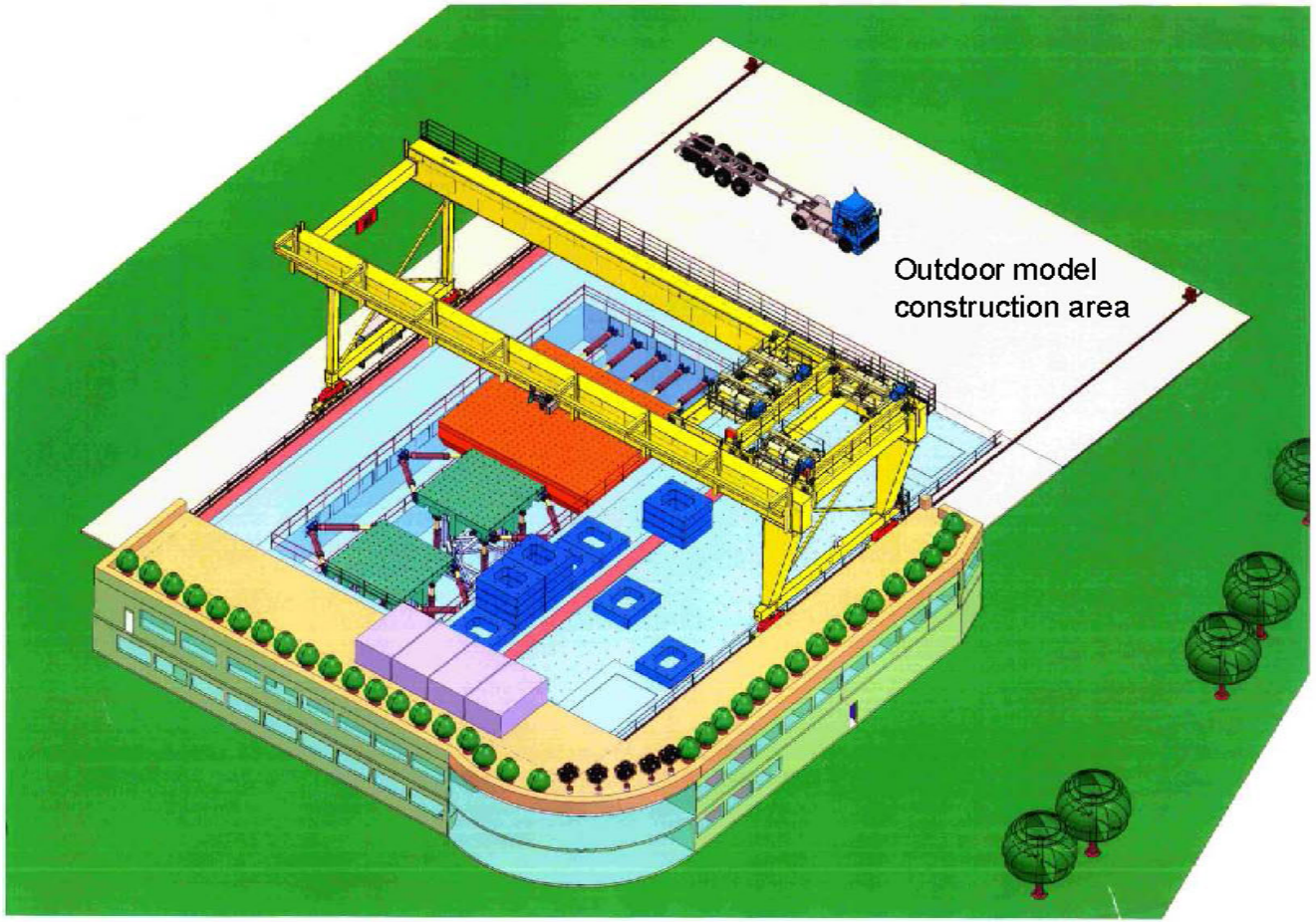
High performance 6 DOF (6x6, 100t, 2g, 2m/s, 1m) shaking tables linked or independent



+ bridge crane 200 t (4x50 t)

+ outdoor construction area

+ numerical facility


Outdoor model
construction area

European Commission

EUR 25012 EN– Joint Research Centre – Institute for the Protection and Security of the Citizen
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Authors: Francesco Marazzi, Francisco Javier Molina Ruiz
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Abstract
The EFAST project has consisted of a design study of a new major seismic testing facility in Europe that will be comparable with important testing installations that are now working or under construction in Japan, U.S.A., China and Taiwan. The presentations by invited experts during the 2nd EFAST Workshop, which was held by the end of the project, emphasized the basic idea that experiments are necessary because reliable engineering cannot still rely only on numerical predictions. The relation between the experimental research and the improvements of the buildings codes in the last decades has also suggested that a consistent experimental activity is fundamental for properly understanding and predicting the real behaviour of complex structural elements. Today in many fields, as in the assessment of nuclear facilities for example, more reliability is required in order to increase the safety, which leads to a newer impulse for experimental testing of components, subsystems, soil-structure interaction effects and so on. The necessity and characteristics of the available testing methods was reviewed with up-to-date examples and studies on aspects such as shaking table, pseudo-dynamic and hybrid testing methods, centrifuge facilities, scale models, soil-structure interaction, control strategies and performance.
Within the EFAST design study as it was presented, several solutions are proposed for the future experimental facility, among which the reference one is a laboratory composed, mainly, of a high performance shaking table array and a reaction structure where both traditional (pseudo-static/dynamic) and innovative testing techniques (e.g. real time hybrid testing) can be applied and combined. These shaking tables can be moved in the trench and can be also rigidly coupled between them, if necessary. A large SDOF shaking table for geotechnical studies is also foreseen in such solution. The discussion of the different solutions covered aspects such as costs (including safety, maintenance and operation), demand of experiments, flexibility and performance among others.

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