2nd Workshop – Ohrid, Sept. 2, 2010
Role of the Research Infrastructure in Performance Based Engineering

Towards a New European Facility for Advanced Seismic Testing (E-FAST)

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Design Study of a European Facility for Advanced Seismic Testing

FP7 \(\rightarrow\) capacities-research infrastructures

Partners of the project

CEA – Saclay (Project leader)
ELSA JRC - Ispra
EUCENTRE – Pavia
TUASI – Iasi
University of Kassel
Design study OBJECTIVES

- Define the features of a new testing facility, complementary to existing research infrastructures in Europe, combining high capacity and flexibility.

- Make progress in advanced testing methods (multiple shaking table control, real time sub-structuring techniques etc.) and carry out demonstration tests.

- Study the technical and financial feasibility of this facility taking into account future networking collaboration with other European and extra-European laboratories.

**Actions**

- Analysis of Research Community needs (Focused on the European Countries)

- Analysis of the technological solutions available: equipments and testing techniques

- Design implementation of a testing facility at the state-of-the-art and inspired to needs
1) **Seismic risk in Europe**

European risk > other industrialized seismic countries (Japan, US)
(morphology, cultural heritage, several underdesigned cases, etc.)

2) **Current tendency of seismic testing**

- Real/large scale testing (reduce uncertainties, requires high performance)
- Several high performance facilities
  - Existing (e.g. University of California San Diego, EDefense)
  - Projects or facilities under construction (China, Korea, Japan)
- New experimental techniques
  - Real-time substructuring
  - Advanced control techniques
  - Distributed testing
1st step: needs → performance

- **Inquiry** (laboratories, industry, construction companies)
  - **1st International workshop:** Challenges, Needs and Open Questions (50 experts)
    - US (Buffalo, NEES IT)
    - TAIWAN (NCREE)
    - JAPAN (CRIEPI)
    - CHINA (Tongji)
1st International WS: Testing needs for research in Earthquake Engineering

- In plan irregular buildings (strength eccentricity, failure criteria)
- Flat slab systems (increase of their behavior factor)
- Precast and prestressed elements and systems (further study of joints, foundation, post-tensioning)
- Masonry buildings and infills (tests of multi-storey masonry buildings, out of plane behavior, contribution to the actual building capacity)
- Infrastructures (Bridges → multi-support excitation)
- Retrofitting (assessment of new techniques and materials)
- Aseismic devices (testing of large isolation devices → dedicated machines, structure response → large displacement capacity)
- Equipment (qualification tests, floor spectra → high acceleration and displacement capacity)
- Soil-structure interaction (only simple configurations, massive heavy specimen because of the soil weight)
1st international Workshop: conclusions

- Need in Europe for high capacity shaking tables
- Adaptability
- Extensibility
- Dedicated set-ups
- Rich instrumentation + field measures
- Capability for real time substructuring in the future
- High numerical simulation capacity before, during and after testing.

Numerical facility
- Networking with other laboratories
- Facilitate low cost access for countries with limited resources
Design proposal: Philosophy

• Go much further than existing shaking table facilities in Europe

• Combination of elements and technology that have already been validated by their operational use in other existing facilities.
  – Technical reasons (*accurate experiments from the 1st day after construction*)
  – Safety reasons
  – Minimize techno-economical risk for potential investors (*divergence from the foreseen date of operational start and from the foreseen budget at the moment of their commitment*)

• Trade-off between dreams and real world. Too high cost (construction, maintenance, handling, specimen transport etc) will kill any chance for the facility to be constructed.
Performance demand (trade-off between cost and performance)

<table>
<thead>
<tr>
<th></th>
<th>Soil-Structure Interaction</th>
<th>Tests on civil engineering structures</th>
<th>Secondary structures or equipment</th>
</tr>
</thead>
<tbody>
<tr>
<td>height of specimen:</td>
<td>6 m</td>
<td>15 m</td>
<td>10 m</td>
</tr>
<tr>
<td>mass of specimen:</td>
<td>500 tons</td>
<td>200 tons</td>
<td>1 - 100 tons</td>
</tr>
<tr>
<td>number of directions:</td>
<td>1</td>
<td>1 - 3</td>
<td>1 - 6</td>
</tr>
<tr>
<td>displacement:</td>
<td>± 1 m</td>
<td>± 1 m</td>
<td>± 1 m</td>
</tr>
<tr>
<td>velocity:</td>
<td>± 2 m/s</td>
<td>± 2 m/s</td>
<td>± 2 m/s</td>
</tr>
<tr>
<td>acceleration:</td>
<td>± 1.5 g</td>
<td>± 2 g</td>
<td>± 2 g (100 tons)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>± 6-7 g (10 tons)</td>
</tr>
<tr>
<td>frequency range:</td>
<td>0.2 - 50 Hz</td>
<td>0 - 50 Hz</td>
<td>0 - 100 Hz</td>
</tr>
</tbody>
</table>
Proposed solution

Principle of the proposal
- Hybrid testing
- Or additional actuators for bounding conditions in all axes
First attempt

• Due to kinematic constraints the minimum dimensions of the table are of about 10mx10m (could be too big for modular tables set-up)
Solution proposed by Kassel University

- based on the needs of testing and data of strong earthquake, UNIKA has proposed a concept of equipment
- different test setups with their criteria were demonstrated

- major features of the concept
  - moveable and flexible test equipment (including table, actuators and reaction system)
  - saving operating costs, suitable for SMEs

=> UNIKA is working on a pre-design of a moveable steel and/or steel-concrete composite reaction system as one of the two construction techniques considered.
Solution proposed by EUCENTRE-Pavia

PIPELINE LAYOUT

- return
- pressure
## Comparison with existing facilities

<table>
<thead>
<tr>
<th></th>
<th>E-DEFENSE Miki</th>
<th>LHPost SanDiego</th>
<th>SEESL -SUNY Buffalo</th>
<th>Proposed configuration</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Size</strong></td>
<td>1 [15 m X 20 m]</td>
<td>1 [6.7 m X 12 m]</td>
<td>2 [3.5 m x 3.5 m] or 2 [7mx7m]</td>
<td>2 [6 m x 6 m] or 1 [6 m x 12 m] + 1 [12m x 12 m] 1dof</td>
</tr>
<tr>
<td><strong>DDL</strong></td>
<td>6</td>
<td>1</td>
<td>6</td>
<td>6</td>
</tr>
<tr>
<td><strong>Displacement</strong></td>
<td>H : ± 1000 mm</td>
<td>H : ± 750 mm</td>
<td>H : ± 150 mm</td>
<td>H : ± 1000 mm</td>
</tr>
<tr>
<td></td>
<td>V : ± 700 mm</td>
<td></td>
<td>V : ± 75 mm</td>
<td>V : ± 750 mm</td>
</tr>
<tr>
<td><strong>Velocity</strong></td>
<td>1 m/s</td>
<td>1.8 m/s</td>
<td>1,25 m/s</td>
<td>2 m/s</td>
</tr>
<tr>
<td><strong>Mass x acceleration</strong></td>
<td>1200 tonsX 0,9g (1000 t.g)</td>
<td>2250 x 1 g (300 t.g)</td>
<td>20 tx 1,15 (23 t.g)</td>
<td>200 tons x 2g (400 t.g)</td>
</tr>
<tr>
<td><strong>Flexibility</strong></td>
<td>No</td>
<td>No</td>
<td>2 tables gap : 1 to 10 m 37 m</td>
<td>2 tables gap : 0 to 20 m 35- 40 m</td>
</tr>
<tr>
<td><strong>Trench length</strong></td>
<td>No</td>
<td>No</td>
<td>Yes (one at the end of the trench)</td>
<td>Yes (all arround the trench)</td>
</tr>
<tr>
<td><strong>Reaction wall</strong></td>
<td>No</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td><strong>Hybrid testing</strong></td>
<td>No</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
</tr>
</tbody>
</table>
Design of technological components for proposed solution:
Table and actuators configuration

Constructor 1
No dead area

Constructor 2
All actuators in the same direction to avoid dilatation problems
Design of technological components for proposed solution: Dynamic actuators

Constructor 1

Constructor 2

Type A: length at mid-stroke $\approx 4.5$ m

Type C: length at mid-stroke $\approx 5.7$ m
Design of technological components for proposed solution:
Hydraulic system configuration

40 power supply accumulators
2x12 (close to the actuators) + 8 + 4

Trade off between pumps and accumulators

6 + 22 pumps

Regulation accumulators
Design of technological components for proposed solution: Reaction mass, foundation & soil-structure interaction

The FE 3D modeling & simulations have been carried out using SAP2000 v. 14. FE used: SOLID elements of $3 \times 3 \times 3$ m.
Design of technological components for proposed solution:
Reaction mass, foundation & soil-structure interaction

Foundation + Equipment

S11 stresses

Max = 0.04 MPa
Min = -0.092 MPa

S22 stresses

Max = 0.138 MPa
Min = -0.086 MPa
Design of technological components for proposed solution: Reaction mass, foundation & soil-structure interaction

2D - FE modeling and simulations using PLAXIS v. 9.2, structure-ground soil 2D Modeling

- Clay 3
- Clay 2
- Clay 1
- Foundation
- Silt
- Sandstone
- Sand 1
- Sand 2
- Sand 3

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Static Analysis Results (2D - SSI)-1

Results on horizontal displacements

Section A-A*: -1.49×10^{-3} m
Section E-E*: -14.9×10^{-3} m
Section G-G*: 0.01 m
Section K-K*: 1.46×10^{-3} m
Design of technological components for proposed solution:
Reaction mass, foundation & wave propagation study

FE with Lysmer boundaries and BE analyses
Design of technological components for proposed solution: Reaction system for structural testing and hybrid applications
Design of technological components for proposed solution: Rigidity, interaction platten-specimen

Chart for lateral (flexural) modes

<table>
<thead>
<tr>
<th></th>
<th>Frequency decrease without local effects</th>
<th>Frequency decrease with local effects</th>
</tr>
</thead>
<tbody>
<tr>
<td>SMART mode 1</td>
<td>9 %</td>
<td>23 %</td>
</tr>
<tr>
<td>SMART mode 2</td>
<td>21 %</td>
<td>33 %</td>
</tr>
<tr>
<td>CAMUS mode 1 (Ox)</td>
<td>-</td>
<td>15 %</td>
</tr>
<tr>
<td>CAMUS mode 2 (Oy)</td>
<td>-</td>
<td>14 %</td>
</tr>
</tbody>
</table>
Design of technological components for proposed solution: Control software

New controller for structural testing (JRC)

Customized controller for ST application developed by UniKa

ST modelling and off-line tuning (EUCENTRE)
Design of technological components for proposed solution: Multimedia rooms & telepresence implementation

• Video Conference Room

Secondary Conference Room

Technical Room
Facilities: Secondary Conference room

Developed into the E-Fast framework

- Thirty people can find place in this room where they have more multimedia devices at their disposal

  The most important information are automatically directed to the technical direction staff into this room

  Projection system, table microphones, laptops and satellite phones increase the interoperativity level
Telepresence Scheme

- Example of hardware election (AXIS solution)

AXIS telepresence system