

# **The European Laboratory for Structural Assessment (ELSA)**

## **The role of earthquake engineering in the society**

Earthquakes are the result of a sudden liberation of energy accumulated at the geological faults (tectonic earthquakes). The consequences of earthquake events are well known to the public: thousands of persons killed or injured each year, thousands of homeless, heavy damage to the building stock, complete disruption of the infrastructure, irreversible damage to the cultural heritage, very large indirect costs resulting from business interruption, loss of revenues, interruption of industrial production.

Predicting the location and intensity of future earthquakes is unfortunately not yet possible. Recent earthquakes such as (Kobe, 1995) and (Umbria, 1997) have shown that *effective prevention has to be based mainly on adequate design, construction and maintenance of new civil engineering structures, and retrofitting of existing structures and monuments lacking appropriate seismic resistance characteristics.*

## **Why experimental testing on large scale models?**

The assessment of the seismic vulnerability of structures is a very complex issue due to the non-deterministic characteristics of the seismic action and the need for an accurate prediction of the seismic responses for levels beyond conventional linear behavior. Satisfactory numerical modeling (based on the finite element method) depends largely upon the availability of a complete characterization of material properties and appropriate calibration of mathematical models able to represent all structural components, including joints. Seismic vulnerability assessment and design of retrofitting solutions for existing structures can be subsequently carried out using calibrated numerical models.

The main objectives of large-scale tests on experimental models are thus:

*to calibrate analytical models suitable for different classes of structures;*

*to validate rules of norms and standards;*

*to validate specific designs of relevant constructions, in particular where a lack of standards occurs.*

## **Testing methods**

Two complementary methods are currently applied in laboratories to simulate the effect of earthquakes on structural mockups (figure 1). Both methods have their respective advantages and drawbacks.

### *Shaking tables*

The most natural testing concept is the use of a shaking table. The model to be tested is fixed to a moving platform to which a motion history representative of past seismic events is applied. The test on a shaking table has the advantage of being dynamically similar to a real earthquake event, but it also suffers from at least two severe drawbacks. First, the amount of power needed to move the mock-up and the table in real time is such that only reduced scale models can be tested, but making reduced models which have dynamic structural behavior fully representative of real large scale structures is unfortunately not possible. Secondly, the test on a shaking table is essentially an open-loop one and does not allow to follow in time with sufficient accuracy the degradation behavior of the structure. Shaking tables exist in different laboratories in Europe (France, Italy, Greece, Portugal).

## Earthquake testing of structures: 2 complementary methods

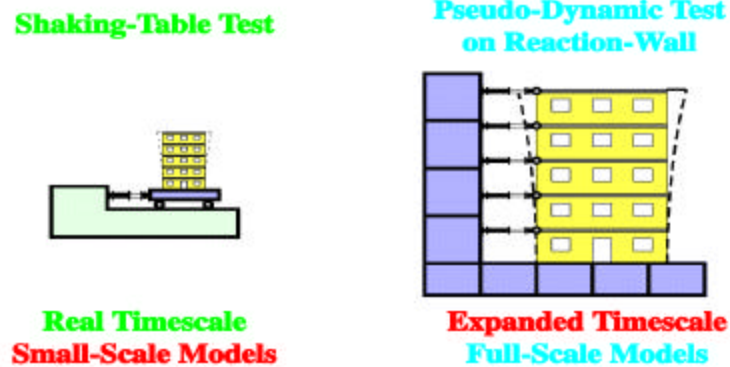


Figure 1

### *Reaction walls*

A reaction wall is a high strength structure consisting of two orthogonal reacting slabs. The model to be tested is fixed to the reaction floor and the loads are applied to it in a pseudo-dynamic manner through the action of hydraulic jacks acting between the structure and the reaction wall. The applied loads represent the inertia and damping effects on the structure and result from the simultaneous use of a numerical model (distributed parameter model numerically integrated in time by a step by step method, calculating the unknown inertia and damping forces) within the control loop. They can also include the effect of missing structural parts in the experimental model.

The tests carried out according to this *pseudo-dynamic method* are performed on a much extended time scale: one spreads out over a long time period (more than 1 hour) the shocks generated in ten seconds by a real earthquake.

Such a controlled simulation makes it possible to implement complex models, reproducing with precision the conditions of an individual earthquake, and to progressively observe the distortions undergone by the structure, and in particular the appearance of cracks. The control technique enables very accurate displacement measurements. The reaction walls allow to test full-scale models with reasonable amount of excitation power, thus at low cost compared to shaking tables. They also offer the possibility to complement the experimental model with other structural parts modeled numerically and introduced in the control loop through a substructuring technique. This is very useful for testing very large civil engineering structures such as bridges for which it is unrealistic to build a complete model.

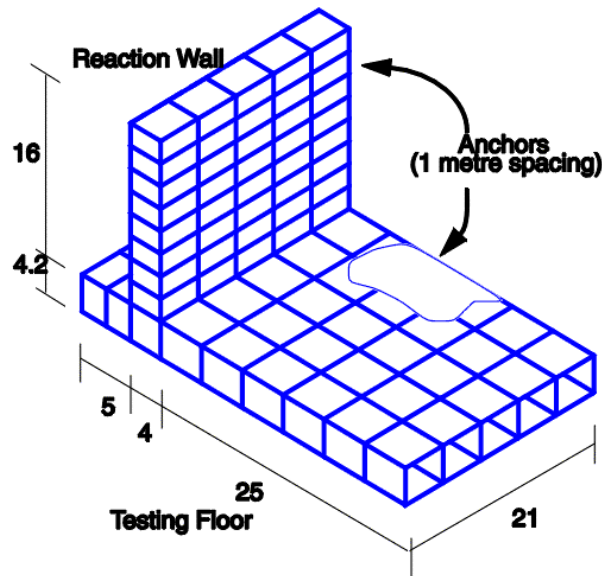
Reaction walls have however also their drawbacks: the loading, although being multi-point, is not distributed exactly in the same way as in the real earthquake event, and nonlinear material properties might be altered due to their dependence with time.

The proper implementation of the *pseudo-dynamic method* is a very complex issue since it is a hybrid, closed-loop process. *Pseudo-dynamic tests cannot be performed without the support of skilled people in the numerical modeling of structures.* Significant expertise is involved in the effective coupling between the experimental and numerical models of the structure.

## The reaction wall at ELSA

The European Laboratory for Structural Assessment (ELSA) at Ispra is equipped with one of the three large reaction walls in the world and the second one in capacity. The largest one is located in Tsukuba (Japan), and the third one is located in San Diego, California. Its load characteristics are given by figure 2.

## Characteristics of the ELSA Reaction Wall



<b>LOAD CAPACITY</b>	<b>REACTION WALL</b>	<b>Bending Moment</b>	<b>200 MNm</b>
		<b>Base Shear</b>	<b>20 MN</b>
	<b>REACTION FLOOR</b>	<b>Bending Moment</b>	<b>240 MNm</b>
	<b>ANCHOR LOAD</b>	<b>Axial Force</b>	<b>500 kN</b>
<b>HYDRAULIC CHARACTERISTICS</b>	<b>FLOW</b>		<b>1500 l/min.</b>
	<b>PRESSURE</b>		<b>210 bar</b>
	<b>ACTUATORS</b>	<b>Load (MN)</b>	<b>( 0.5 - 1.0)</b>
		<b>Stroke (m)</b>	<b>( 0.25) - ( 1.0)</b>

Figure 2.

The computer control implementing the pseudo-dynamic method at ELSA is a unique feature of the installation (figure 3). It has been entirely designed and achieved by the ELSA team.

## The PSD method at ELSA

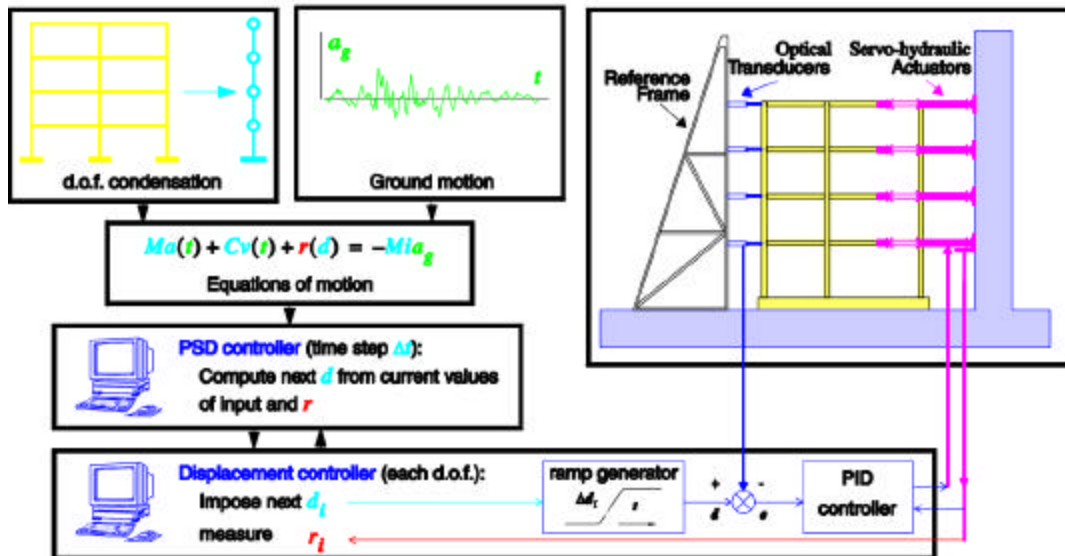


Figure 3: control system of reaction wall at ELSA

The scientific activity that ELSA generates attracts both confirmed and young researchers from all over Europe.

### European Collaboration

To obtain the maximum benefit of the ELSA facility, it is used in the framework of an integrated Community-wide research program making full use of existing expertise and complementary facilities within the Member States.

To this end an Association of Structural Mechanics Laboratories (more than 30 partners) has been set up to jointly develop detailed research programs.

The collaborative networks emanating from the Association are receiving support from the TMR program of the European Commission.

### Prenormative research at ELSA

The Eurocodes - the European provisional standards for constructions - are being prepared by the European Committee for Standardization (CEN, Technical Committee No 250) under mandate of the European Commission. The procedure involves a first release as provisional norms. After a period of three years, during which comments are expected, the Eurocodes are intended to be accepted as European Norms. The process of approval of each Eurocode has reached different stages.

In particular, Eurocode 8 specifies standards that buildings should comply with to withstand vibration caused by road, rail traffic and earthquakes. Since its establishment, the ELSA laboratory has been used in close co-operation with the European experts on Earthquake Engineering to provide the necessary validation experiments for the final drafting of Eurocode 8.

### **Support to the advances in earthquake and vibration engineering**

The ELSA research team is strongly engaged in supporting the development of new techniques to prevent the effects of strong earthquakes and, more generally, to control the vibration of large structures such as buildings and bridges. Relevant contributions are currently made in full/large scale testing of structures protected by base isolation, energy dissipation devices and active control systems. These researches, run under international collaboration, will provide data for future design standards.

### **Preservation of cultural heritage**

Preservation of historical monuments is one of the challenging tasks of our society. In Europe, even more than in other continents, it should be a priority because of the large number of monuments having an inestimable cultural value. The recent Umbria/Marche, Italy earthquake events have shown how vulnerable are ancient constructions under seismic loading. Very important monuments (e.g.: Basilica of S. Francesco, Assisi) have suffered irreversible damages and very old villages have been seriously affected.

The SMU is involved in projects dealing with the vulnerability assessment of historical structures (Geraci palace in Palermo and S. Vicente de Fora Monastery in Lisbon) and the validation of retrofitting methods. These projects consist in the combined numerical modeling and experimental testing of large-scale models representative of parts of these monuments.

### **Competitive actions and third party work**

During 1997, ELSA has contributed to various share-cost actions under the BRITE and Environment and Climate Programs. The work carried out under the different shared cost actions aimed at studying the effects of particular geological conditions in the seismic action, as well as to enforce the adoption of new materials and technologies in both the construction of new structures and the retrofit of existing ones. Third party work has been achieved to assess the resistance to earthquakes of nuclear engineering structures and the seismic vulnerability of historical monuments (see above).

### **International collaboration in earthquake engineering**

In addition to the European partnership in the work carried out at ELSA, the world-wide dimension of the problem represented by the earthquake safety of structures has been recognized, and collaborations with foreign countries have been established. In particular collaboration agreements have been signed with relevant research institutions of Japan, USA, Armenia and Taiwan while other agreements are underway. The main aim of the international collaboration is the comparison of construction codes in view of harmonization and the exchange of competences in innovation techniques for seismic protection.

### **Information**

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