SEISMIC TESTING CAPABILITIES OF CEA SACLAY LABORATORY - DESCRIPTION-EVOLUTION-DEVELOPMENT INTERNATIONAL COLLABORATION

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Abstract

The seismic testing facility, TAMARIS, is part of the mechanical studies Laboratory located in CEA Saclay research centre near Paris. It has a staff of about 20 engineers and technicians. Its objectives are model development, validation, calculation methods development, qualification, codification, and qualification of components. It has four shaking tables, a reaction wall and a test pit, for long specimens. The main table, AZALEE, has a 6mx6m plate, with a 100 tons payload. It allows movements in 3 directions with 6 degrees of freedom. The Laboratory is working on different national and international programs related to the seismic behaviour of buildings, structures, components and equipment. A detailed description of the facility will be presented together with some main features of the recent research programs for buildings and equipment. The Laboratory is involved for many years in International collaborations and networking, especially in the framework of European programs (ECOEST and ECOLEADER). The importance of such collaborations will be emphasized.

INTRODUCTION

The mechanical seismic studies laboratory (EMSI) belongs t o the Direction to the Nuclear Energy of Commissariat à l'Energie Atomique (CEA). This Laboratory, located in Saclay, near Paris, has carried out tests of R&D and seismic qualification for more than 35 years. The mission of the laboratory is to study and check the seism resistance of the civil engineering and the equipment. The activity is characterized by four essential topics:

- The development of methods for seismic analysis,
- The development of complex models of structures,
- Seismic tests related to the validation of methods and analyses,
- Seismic performance tests of equipment or elements of structure of civil engineering as well as performance tests in all the fields requiring of the excitations at low frequencies.

The laboratory works mainly with EDF, COGEMA, FRAMATOME and the Safety Authorities as well as for the European Community via collaborations with various European universities (Aachen, Ancona, Bristol, Liege, Patras, Pavia, Rome, Sheffield etc...). The installation is also opened to any external request for performance tests or R&D.

For all these activities, the laboratory has a whole of numerical and experimental means. The numerical studies are performed by means of the computer code by finite elements CAST3M (ex CASTEM 2000) developed at the CEA and which allows calculations into linear and nonlinear behaviour. For the experimental part, the laboratory has several mobile plates of large capacity and walls of reactions. These test facilities (TAMARIS) are the subject principal of this presentation.

EXPERIMENTAL TEST FACILITIES TAMARIS

TAMARIS represents the largest test facilities within the community European and have the largest shaking table in Western Europe Laboratory EMSI is apart of ECOLEADER consortium gathering 6 European laboratories (BRISTOL University, LNEC (Lisbon), LTUA (Athens), EMSI (Saclay), JRC (Ispra), ENEL [ISMES](Seriate)).

TAMARIS is composed of 4 shaking tables (VESUVE, TOURNESOL, MIMOSA, AZALEE), of a 15 depth m pit (IRIS) and of a reaction. Wall (Figure #1). All these test facilities use a common hydraulic power including 6 hydraulic groups allowing a constant maximum flow of 2130 litres/minutes.
The 4 shaking tables are installed on a reaction mass of 16 m X 16 m and 8.5 m thickness with a total weight of 2500 tons. This reaction mass is put on isolating devices with springs and dampers filtering all vibrations above 1 Hz.

Shaking table VESUVE

First table brought into service at the laboratory in 1969 and renovated in 1976, this table of 3.1 m X 3.85 m is actuated by an electro hydraulic jack of 350 kN with a stroke of 250 mm. The aluminium table admits a payload of 20 tons. Six mechanical bearings ensure guidance up to 70 Hz. This table is mainly used for R&D tests.

Shaking table TOURNESOL

The table TOURNESOL, operational since 1976 is biaxial horizontal + vertical. The aluminium plate of 2 m X 2 m admits a payload of 10 tons. It is actuated by 1 horizontal jack of 100 kN and 250 mm stroke (flow of the servo valve: 640 litres/minute) and by 2 vertical jacks of 100 kN each one (flow of each servo valve: 340 litres/minute) of 200 mm stroke. This table being biaxial, is mainly used for seismic qualification tests

Shaking table MIMOSA

The mono axial shaking table MIMOSA of 2 m X 2 m was brought into service in 1982. It has a payload of 10 tons and is actuated by a jack of 500 kN high frequency. Six hydrostatic bearings TEAM guide the table, allowing tests up to 300 Hz. The stroke of the jack is limited to 2 inches. This table was especially studied to carry out tests on reduced scale models by using a law of similarity of speed.

Shaking table AZALEE

This 6 m X 6 m Shaking table (Figure # 1), the biggest shaking table of the laboratory is in service since 1990.. Its 25 tons aluminium plate takes loads up to 100 tons. It is actuated into horizontal (OX, OY) by 4 electro hydraulic jacks of 1000 kN (2 in each axis) and into vertical (OZ) by 4 jacks of 1000

kN. Each jack is equipped with 3 servo valves of 640 litres/minute. The static compensation of the load is ensured by 4 pressurized supports. The stroke of the jacks is 250 mm in horizontal and 200 mm in vertical. In order to ensure better performance, 12 accumulators of 250 litres unit have been added so, to ensure under seismic excitations maximum speeds higher than 1 m/s in the three directions. Seismic accelerations up to 1.8 g can be carried out on the table or shocks (1/2 sinus) for mechanical qualification tests up to 4 or 5 g. This table is mainly used for tests on models of civil engineering and for qualification tests on large equipment.

Pit IRIS and reaction wall

A pit was associated to the shaking tables. It acts of a concrete cylinder of 1059 tons, 15 m depth and 4.2 m diameter, which makes it possible to establish jacks at various places for multipoint excitations on great height structures. The pit has been studied to be able to test control rod of nuclear reactors. On the concrete mass supporting the shaking tables, a reaction wall with small size (length 5 m, height 4 m) has been built in order to be able to carry out static or quasi-static tests.

CONTROL AND ACQUISITION SYSTEMS

Two control systems and 2 acquisition systems are associated to the test facilities.

Control Systems

The tables are controlled by software developed by Signalstar company established on PC (DELL 410). This software allows the realization of sine sweep tests for research of Eigen frequencies or the qualification with control in one or more points on the effective value, the peak value, or filtered value. It allows also to realise random excitations in one two or three directions, - excitations by shocks (1/2 sinus, etc....) and seismic excitations in one to three directions using real time histories or synthesized time histories.

For sine and random tests, this software works in closed loop. For the seismic tests, it works in open loop. The transfer functions are determined during initial tests at low level of acceleration and are used to determine the control signal allowing to obtain the required acceleration on the table

Acquisition systems

During tests, one or two calculators can be used to record measurement channels (64 channels each). A modal analysis software allow to determine Eigen frequencies, damping and to draw the modal shape.

EXAMPLES OF TESTS CARRIED OUT BY THE LABORATORY IN VARIOUS FIELDS

R&D in the field of the civil engineering

Within the framework of the European Community and contracts between the CEA, the National Federation of Building industry (FNB), the Ministry for the Equipment the Ministry for National Education and EDF many tests (programs CASSBA, CAMUS, CAMUS 2000) on walls were carried out these last years. Models on reduced scale (1/3) of 8 or 5 floors were manufactured and tested on AZALEE shaking table (figure # 2).

These models consist of 2 concrete walls slightly armed and of floors in charge of concrete masses to represent the load of the floors and to be in agreement with the similarity laws (law in acceleration). These models with a mass of 40 tons to 85 tons are subjected to some series of seismic excitations at increasing levels until the damage and collapse. During tests, accelerations, displacements and velocity are measured at each floor level. Strain gauges inside the walls measure the deformations the steel reinforcement and measure the openings of cracks.

The data processing is carried out in real time at the end of each test in order to determine bending and the shearing force moment. These test results are compared with the calculations results to determine the excitation level of the following test in order to as well as possible adjust the test routine according to the required answers. The main objective of the tests is to develop and qualify computer codes able to analyse the non linear behaviour of structure, taking into account detailing (confinement, gap, ..) For this reason, other tests on structures with concrete such as wall, concrete frame, without or with bricks, etc... are carried out on AZALEE table (figure # 2). Non linear analyses are also used for the calibration of tests.

Table 1 : characteristics of the tests facilities

Test facility	AZALEE	VESUVE	TOURNESOL	MIMOSA	IRIS
Actuatrices axes et force (kN)	OX = 2000 OY = 2000 OZ = 4000	OX = 350	OX = 100 OZ = 200	OX = 500	3 time 25 kN or more
Dimensions (m)	6 X 6	3.1 X 3.8	2 X 2	2 X 2	12X 4.2X4.2
Mass of the table (tons)	25	4.2	1.2	1	
Payload (tons)	100	20	10	10	
Excitation axes	6 DDL OX + OY +OZ	mono axial horizontal OX	biaxial horizontal + vertical (OX + OZ)	mono axial horizontal OX	On request
Maximum displacement (mm)	OX et OY ± 125 OZ ± 100	± 100	OX = ± 125 OZ = ± 100	± 12.5	± 125
Maximum velocity (m/s)	OX= 1 OY = 1 OZ = 1	1.0	mono axial OX = 2 OZ = 1.3 axial OX = 1.4 OZ = 0.7	0.6	1
Maximum acceleration (g)	OX = 1 OY = 1	1.2	OX = 1 OZ = 1.5	4	
Frequency range (Hz)	0-100	0-100	0-100	0-300	0-30
Height of the specimen (m)	12	12	12	12	27

Notas : OX et OY horizontal axes - OZ vertical axis

R&D in the nuclear field of the equipment

The laboratory takes part in the development and the validation of linear and nonlinear models of nuclear equipment. Many tests were carried out on elements and sections of piping for fast breeder reactor, on fuel assemblies (figure # 4) and control rod, on electrical equipments and their anchoring on the ground The models developed with the finite elements computer code CAST3M are validated by comparison with test results obtained on shaking tables.

Seismic qualification of equipment

The laboratory, although specialised in R&D tests for the nuclear energy, opens its test facilities for other industries and realized qualification tests in all fields of activity. Seismic qualification tests are carried out on various equipment (for example electrical equipment , air coolers [see photography N°3] fuel storage racks, as well as mechanical environment tests on equipment having to resist to severe mechanical environment such as transport by road, , by train, by boat or airplane [figure # 3]

INTERNATIONAL COOPERATION

The laboratory is involved for many years in international collaboration and networking especially in the framework of European funded programs (ECOEST, ECOLEADER …) together with 5 other main seismic testing laboratories (BRISTOL (England), LNEC (Portugal), LTUA (Athens), ISMES (Italy), ISPRA (Italy)). One main objective is to allow European research team to use adequate testing facilities for R&D programs, in order to enhance and to coordinate R&D in this field. In addition, cooperative research programs aiming to develop testing capabilities and methodologies participate to the improvement of shaking table control and to the overall quality of the tests. Around this testing collaboration core, other research team from universities are involved in networking activities, benchmarks, organisation of workshops ….The laboratory has launched international benchmarks concerning the shear walls experiments CAMUS. About 20 international teams participated to them. Results have been presented at different conferences. Extension of such activities is a very important point in order to improve and optimize the seismic protection of our society.

FUTURE ACTIVITIES OF THE LABORATORY

The experimental activity of the laboratory has strongly evolved/moved for a few years. The study of the equipment yielded the place gradually to the studies of civil engineering, imposing increasingly powerful test facilities in particular due to important dimensions of the models

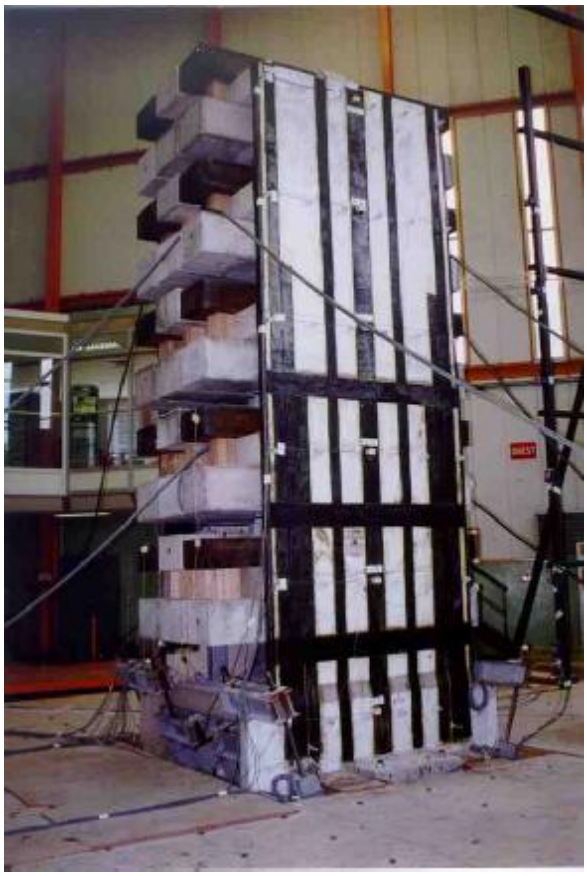
The laboratory is in a period of thought for the definition of an evolution of its test facilities. The principal motivations are:
- to increase the performances in displacement, velocity, acceleration and payload,
- to have a greater flexibility in use,
- to be able to performed more or less complex tests,
- to have the possibility of coupling tests and calculations while using for the same test shaking tables and reaction wall (real time dynamic hybrid tests),
- to be able to build and transport larger models.

In the current state of the thought, the project seems to direct towards a extension of the current building with the realization of 2 new shaking tables of 3 m X 6 m mobile and of a long wall of reaction. The two shaking tables could move separately or together, bolted together or not (figure # 5). The model or a part of model, excited by the table could be submitted to dynamic loadings applied by hydraulic actuators fixed to the reaction wall to reproduce loads induced by a part of the simulated structure.

The shaking table characteristics could be: displacement 1 m, velocity range 2 to 3 m/s, maximum acceleration 2 g with 200 tons and 6 to 7 g for a payload from 10 to 15 tons.
These two tables of a very great flexibility would allow the realization of tests on complex structures [piers of bridge, piping systems…].

Coupled between them, they could replace AZALEE shaking table in the event of unavailability and ensure the permanent using of an important test facility for the nuclear park.

Figure # 1 – View of the test facilities



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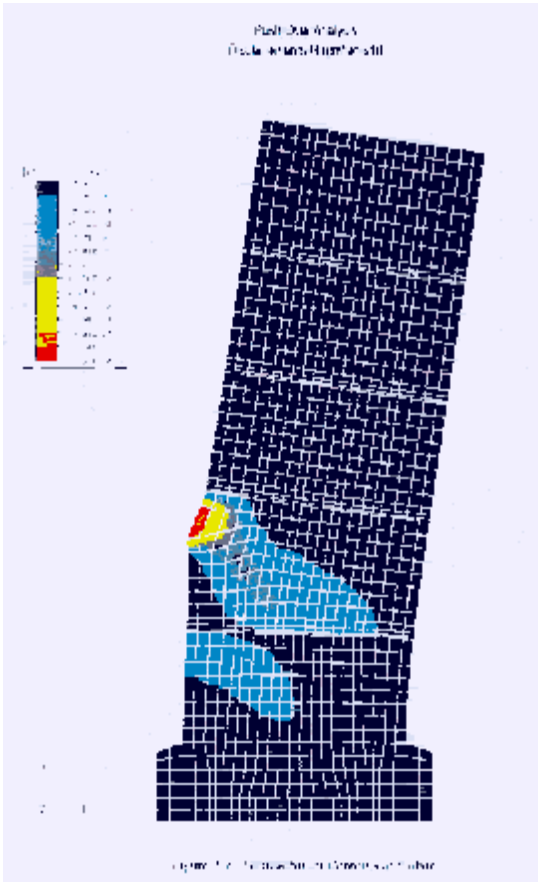

Figure # 2 – seismic tests on concrete wall – View of the mock-up and calculation results

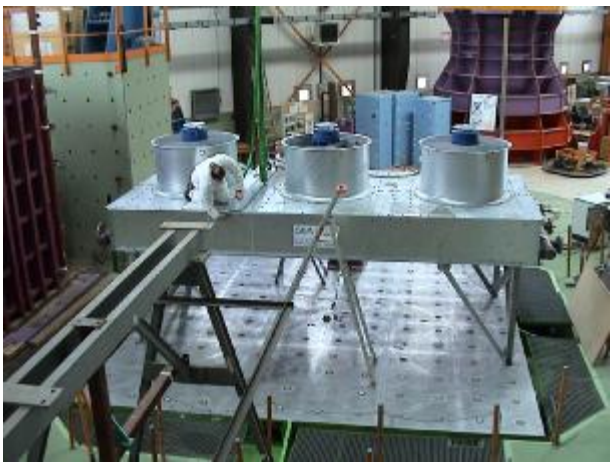

Figure # 3 – Seismic qualification tests on equipment: Cooling system – Electric cabinets

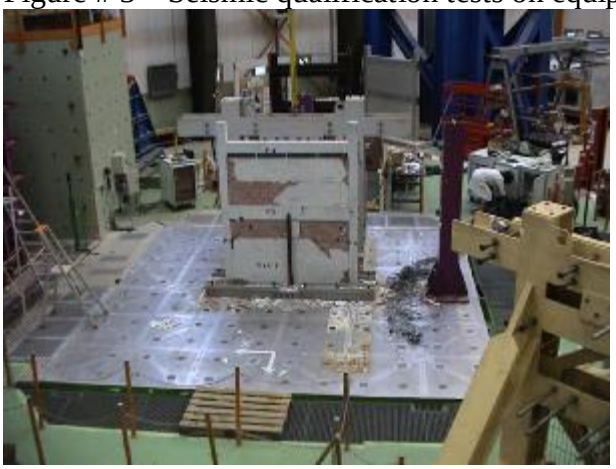

Figure # 4 – seismic tests - concrete frame with masonry – fast breeder reactor core scale 1.

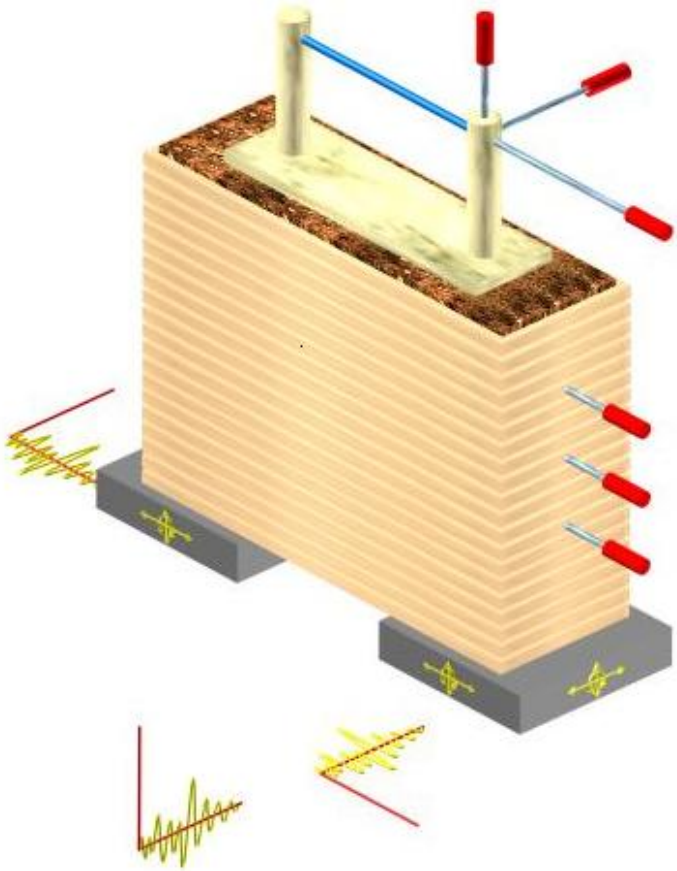

Figure # 5 – New test facilities