Background Material to Pierre Sollogoub's Presentations

SIMULATION OF THE CONTROL ROD DROP UNDER SEISMIC EXCITATIONS: EXPERIMENTAL PROGRAM

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EXPERIMENTAL PROGRAM

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ABSTRACT

This paper describes the experimental program that will be performed at the end of 1998 at the CEA Saclay on a specially constructed analytical mock-up of a control rod. The purpose of these tests is to partially validate the current methodology of the drop time numerical calculations of a PWR (pressurized water reactor) control rod under seismic excitations. The French nuclear partners (EDF and FRAMATOME) are involved in this program.

KEYWORDS

Control rod drop time - Analytical validation tests - Seismic excitations

1. INTRODUCTION

A validated calculation methodology is necessary to predict the drop time of the control rods in a power plant under seismic excitations. The numerical study of the control rod drop under seismic excitations needs to modelize complex phenomena such as friction, shock, blocking and unblocking...

The objective of the experimental program described in this paper is to built an analytical mock-up and to perform sound laboratory tests, well instrumented in order to partially validate the current methodology, more especially the parameters concerning the braking or the stop of the drop : formulation of the contact forces, influence of the water, influence of the gap between the rod and the elements of the drop channel...

2. EXPERIMENTAL FACILITY

The experimental tests program will be performed at the Seismic Mechanics Laboratory of the CEA Saclay. The tests will be carry out in the IRIS pit (Figure 1). This pit allows testing of specimen up to 25 m high. The diameter of the hexagonal pit is about 4 m and the depth 12 m. The lateral walls are equipped with anchoring devices. Hydraulic actuators can be fixed to impose vertical or horizontal dynamic excitations at the structure to be tested.

3. ANALYTICAL MOCK-UP

A specially analytical mock-up has been designed and built for the experimental program. The figure 2 presents a principle sketch of the mock-up.

The analytical control rod is formed by two linked beams : a rigid beam at the top of the rod (about 5 m high), which simulates the rod drive and an equivalent beam at the bottom (about 4 m high) which simulates the 24 rod cluster control assemblies (RCCA). The spider and the end pieces of the real control rod are not simulated in the design of the analytical rod. The scale of the rod is about one. The mass of the analytical rod is quite the same than the real one.

As figure 2 shows, seven discrete circular stops and a guide tube constitute the drop channel. The dynamic motions will be imposed at three of these circular stops (stops V1, V2 and V3) by three hydraulic actuators. The design of the experimental mock-up will allow 2D and 3D dynamic excitations. For the 3D configuration, one of the hydraulic actuators will be fixed at 90° of the two other actuators. The experimental drop channel is not really representative of the real one. The altitudes of the mobile stops correspond approximately :

- *at the top of the continuous guidance of the control rod guide (stop V1),*
- *at the top of the guide cards of the control rod guide (stop V2),*
- *at the CRDM (Control Rod Drive Mechanism) in the pole and gripper area (stop V3).*

The intermediate fixed stops will limit the horizontal displacements of the rod during the drop. The F1 stop corresponds to the beginning of the fuel assembly.

The gaps between the stops and the rod are less than 5 mm.

During the drop, the rod will be linked at an external device that will introduce a braking force which simulates the slowing effect of the hydraulic (or hydromechanical) forces existing in the real drop channel. Thanks to this device, we will be able to reproduce a reference drop kinetic (without dynamic excitations) close to the real recorded kinetic.

The mock-up has been designed in order to allow tests without or with water. An external tube will retain the liquid around the rod during the drop. This water will be unpressurized and without forced flow.

4. EXPERIMENTAL PROGRAM

The main steps of the experimental program will be the following :

- Characterization tests of the mock-up : natural frequencies of the rod, global friction coefficient,...
- Drops with initial static shape of the rod, with increasing amplitude,
- Drops under simplified dynamic excitations : white noise and sinus,
- Drops under seismic excitations.

These tests will be performed without and with water for the 2D and 3D configurations.

The parameters that will be recorded during the tests are the following :

- The drop time,
- The vertical displacement, velocity and acceleration,

- The shock forces on the mobile stops and some fixed stops,
- The relative displacements between the mobile stops and the rod, in two horizontal directions.

5. NUMERICAL MODEL

A numerical model has been developed for predictive calculations and the analysis of the tests. The calculations are performed with the finite elements numerical code CASTEM 2000 developed by CEA.
The figure 3 shows a sketch of the model. The rod is modelized with beams elements. Specific conditional links have been defined to take into account the shocks between the rod and the stops or the guide tube. Some predictive calculations have still been realized. The figure 4 shows an example of the comparison of the vertical displacement and velocity of the rod without and with a seismic excitation of the stops.

6. CONCLUSION

This paper has presented the analytical mock-up and the experimental program that will be performed at the end of 1998 at the CEA Saclay to study the drop of the control rod under seismic excitation. This study is a part of a program of validation of the calculation methodology of the control drop time under seismic excitations. An other complementary experimental program will be performed on a full scale facility at the CEA Cadarache which includes real components and simulates the main coolant flow coming up through the fuel assemblies. The objective of this complementary program is to verify the seismic braking effects predicted by computation after taking into account the results of analytical tests.

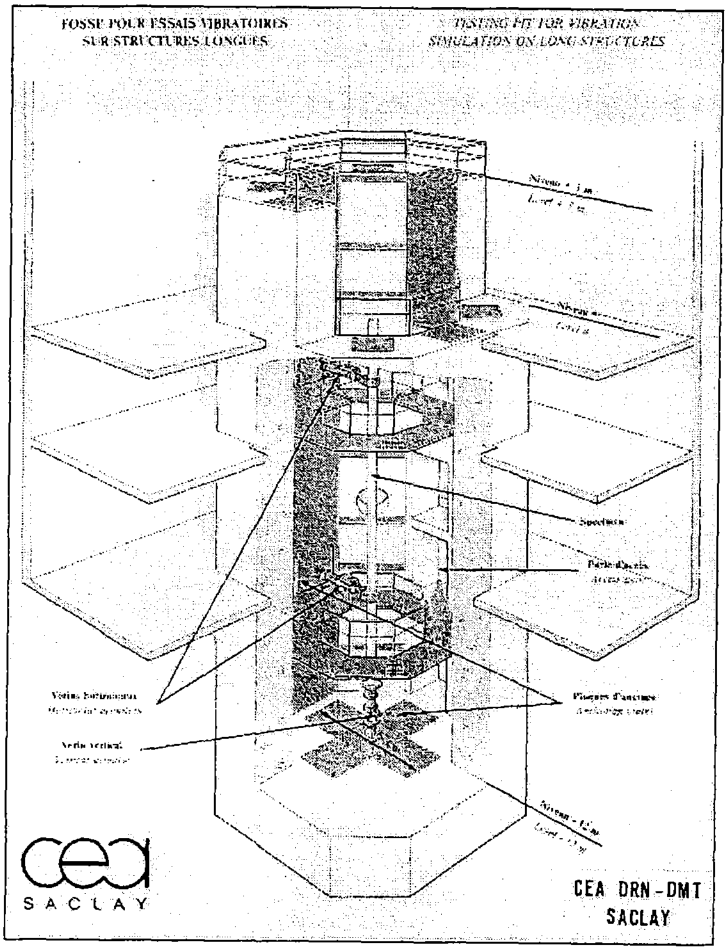

Figure 1
IRIS Pit

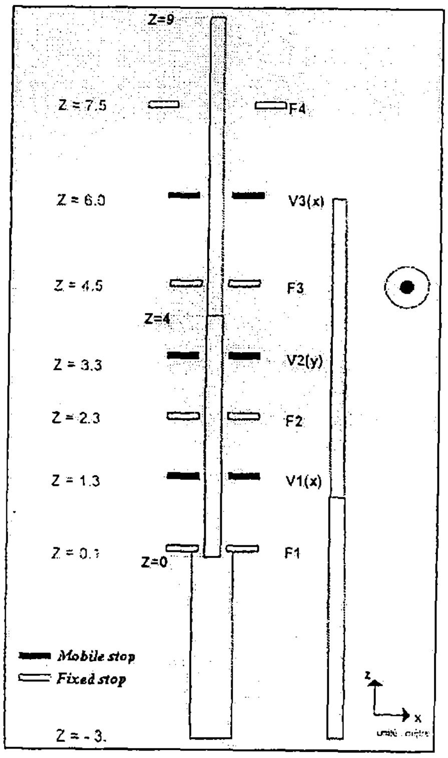

Figure 2
Mock-up principle sketch

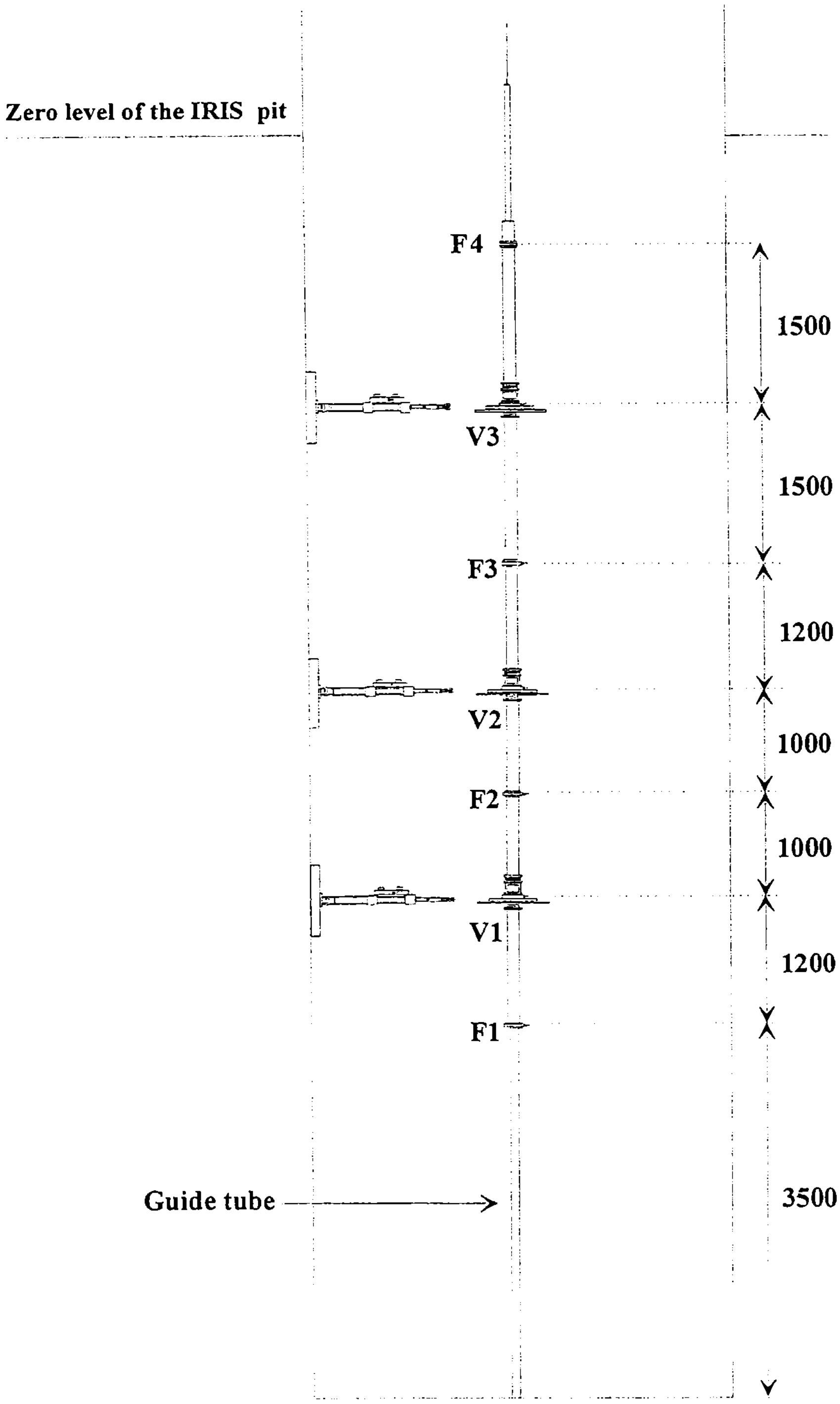

Figure 3
Sketch of the analytical mock-up in IRIS pit

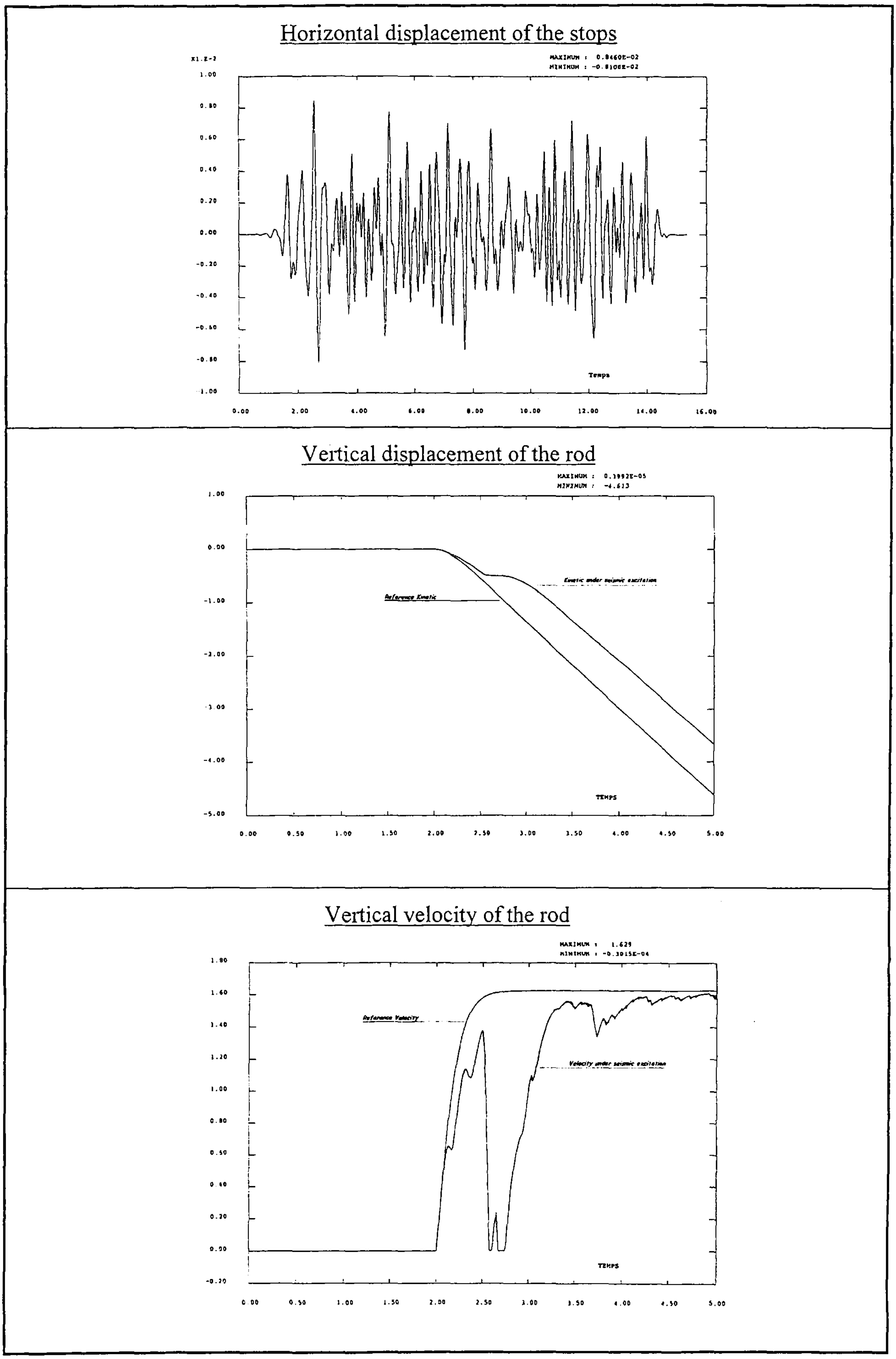

Figure 4

An example of calculations results