DYNAMICS LABORATORY OF THE NATIONAL UNIVERSITY OF MEXICO

by

J. Abraham Díaz[I] and Enrique del Valle[II]

SYNOPSIS

The Institute of Engineering, National University of Mexico, has recently installed a new dynamics laboratory whose main feature is a 2.4 m by 4.5 m shaking table with one horizontal degree of freedom. The table is driven by means of a 75 tn electrohydraulic actuator, electronically controlled in order to simulate different types of motions. The Laboratory is devoted to do research in Earthquake Engineering.

INTRODUCTION

Experimental research in Seismic Engineering is a topic of great interest since it complements research focused to the development of analytical methods of structural analysis and design.

Adequate facilities, especially designed and constructed, are necessary to perform experiments in accordance with present scientific development. The need to design and construct the facilities here described, which will be dedicated to perform experimental research in Seismic Engineering, was established taking into account all these and the experience attained by the Institute of Engineering[1,2,3].

The Institute of Engineering has a 4.80 m x 4.80 m shaking table with one degree of freedom in the horizontal direction, excited by an eccentrical mass vibrator capable of generating a maximum harmonic force of 5 tn.

That table shows several inconveniences when studying the behavior of different kinds of structures subjected to seismic excitations: mainly to generate only harmonic excitations, to be restricted to relatively low frequencies, and to have only one degree of freedom.

Although, it is generally accepted that the horizontal component of such a movement produces the greater effects, it is also recognized that some structures behave differently when subjected to simultaneous horizontal and vertical vibrations than when subjected to one component only.

DESCRIPTION OF THE FACILITY

The Dynamics Laboratory is situated in an area bordering the National University. That place was chosen because of the convenience of having the laboratory building away from other buildings (fig 1).

[I] Head of Dynamics Laboratory, Institute of Engineering, National University of Mexico

[II] Dean, School of Engineering, National University of Mexico

The main feature of the Dynamics Laboratory is a shaking table with plan dimensions 2.4 m x 4.5 m. The table has one horizontal degree of freedom. It is planned that another vertical degree of freedom be added in the future.

The shaking table was built with a combination of reinforced and prestressed concrete. It consists of a 40 cm thick rectangular slab stiffened by two heavy longitudinal ribs 10 cm wide that extend 90 cm below the slab's bottom surface and by two lighter transverse ribs (fig 2).

The shaking table weighs 15 tn, and has been designed to bear test specimens up to 15 tn, it rests on four pedestals (vertical posts made of 4 inch diameter double extra strong steel pipe). Each pedestal has swivel joints at both ends that allow rotations as the table moves. The total length of each pedestal, including swivel joints, is 120 cm (fig 2). These pedestals will be replaced in the future by electrohydraulic actuators to add the vertical degree of freedom.

The shaking table is founded on a reinforced concrete structure that lies over a 25 m deep basaltic rock stratum. The foundation has the form of an open box with 50 cm thick walls. Its outside dimensions are 7.10 x 3.70 x 3.00 m, and its inside dimensions 6.10 x 2.70 x 2.50 m. The actuator's force reacts against a reinforced concrete beam monolithic with the massive foundation. The foundation weighs 150 tn.

An overall view of the laboratory is shown in fig 3. The system may be considered as divided into three parts: 1) Shaking table, 2) Control, 3) Signal acquisition and processing.

The control subsystem consists of: a) 75 tn capacity electrohydraulic actuator equipped with a 640 l/min (170 gal/min) servo-valve (fig 4). The actuator is linked at both ends by swivel joints. b) A hydraulic power supply generates the necessary pressure for the actuator and the hydrostatic bearings. It normally operates at 210.9 kg/cm^2 (3 000 psi), powered by a 200 HP motor and a 416 l/min. (110 gal/min) pump. The hydraulic hoses have several pressure accumulators to provide for intermitent usage of the equipment. c) Hydrostatic bearings, that restrict the shaking table's transverse displacements and only permit vertical and horizontal longitudinal movement. d) Electronic control, it is carried out by a closed circuit servohydraulic control system.

The actuator is controlled by a servo-valve that can be programmed to furnish periodic motion by means of a function generator, or random motion with signals recorded in magnetic tape, or with signals generated by a minicomputer.

The closed circuit control system basically operates by comparing the desired signal (program) with the output signal taken from a transducer placed in the actuator, thus providing corrected signals that compel the shaking table to move according to the programmed signal. Should any difference between the command and feedback signals be detected, a correcting signal is generated and sent to the servo-valve which corrects the difference. This process takes place 10 000 times per second, allowing the response to be practically equal to the input signal within the frequency range of operation.

The control subsystem was supplied by MTS, Systems, Corp. Minneapolis, Minn.

The data acquisition and processing subsystem conditions, records, and stores the input signals from acceleration-time histories. A minicomputer, whose main purpose is the acquisition of data during a test, is used to integrate the velocity-time history which is in turn integrated to obtain the displacement time history.

DYNAMIC BEHAVIOR OF THE SHAKING TABLE

Several tests were carried out to determine the performance capabilities of the seismic simulator system (shaking table and control subsystem).

The oil column resonant frecuency was found to be 31.5 Hz with unloaded table, and 16.5 Hz with the table loaded with a 15 tn non-resonant specimen. The following acceleration levels were obtained in the maximum sinusoidal performance tests in which the table was loaded with 5 tn non-resonant specimen: 0.625 g', 2.08 g', 3.2 g' and 3.2 g' at 3, 10, 60 and 80 Hz, respectively.

The maximum distortion was 15 per cent at 5 Hz and the minimum distortion was 3.6 per cent at 50 Hz with the table loaded with a 15 tn non-resonant specimen.

Actual data of the vertical cross-axis motion was taken at several frequencies to make a comparison with theoretically calculated values. The results indicated discrepancies between calculated and measured values.The theoretical values were obtained based on the assumption that the pedestals were in vertical position when the horizontal actuator was in the midstroke position, and, also, that there was no foundation motion.

In order to know the performance of the pedestals, vertical crosstalk accelerations were measured along the pedestals'vertical axis. Notorious differences were found between the response of the accelerometers placed immediately below the lower joints and the response of those placed above those points. The general trend was of an increase of vertical crosstalk amplification as the accelerometers were closer to the top.

It was thought that part of the problem could be attributed to insufficient smoothness in the contact surface of the joints.

To reduce the amount of crosstalk, the alignment of the table, the verticality of the pedestals, and the rigidity of the foundation is being checked.

It is convenient to point out that the aforementioned problems appear only at frequencies above 30 Hz, and that the table can be considered to have good behavior in the 0 to 30 Hz interval.

USE OF THE SHAKING TABLE

The first research program in which the shaking table will be used is an investigation on the behavior of sands under dynamic loads. Sand specimens will be tested under simple shear conditions in a 30 x 60 x 90 cm mould[2].

Other programs include the continuation of the study of the dynamic behavior of rockfill dam models built with brittle material[1] and, more generally, the research in Earthquake Engineering.

CONCLUSIONS

Preliminary tests using the shaking table indicate that the system will provide a satisfactory means for testing structural components or models under sinusoidal motion or other excitations simulating earthquakes.

ACKNOWLEDGMENTS

The shaking table facility was developed with the financial support of UNESCO and UNAM.

The authors express their appreciation to the members of the Dynamics Laboratory Research Staff, National University of Mexico, for their collaboration during all the phases of the installation, instrumentation and operation of the shaking table facility.

This article was written on the basis of reference 4.

REFERENCES

1. Díaz, A and Rascón, O A, "A new material for dynamic tests of rockfill dam models," *V World Conference an Earthquake Engineering,* Rome (1973)

2. Díaz, A, Weckmann, O and Iturbe, R "Licuación de Arenas, Primera Parte (Sand liquefaction, First Part", *Instituto de Ingeniería. UNAM,* Report 319 (Sep 1973)

3. Del Valle, E, "Estudios preliminares para la construcción de una nueva mesa vibradora (Preliminary studies for the construction of a new shaking table)", *Instituto de Ingeniería, UNAM,* Internal report (Feb 1972)

4. Díaz, A *et al*, "Laboratorio de dinámica estructural, Instituto de Ingeniería, UNAM *(Structural dynamics laboratory. Institute of Engineering, UNAM)",* Instituto de Ingeniería, UNAM

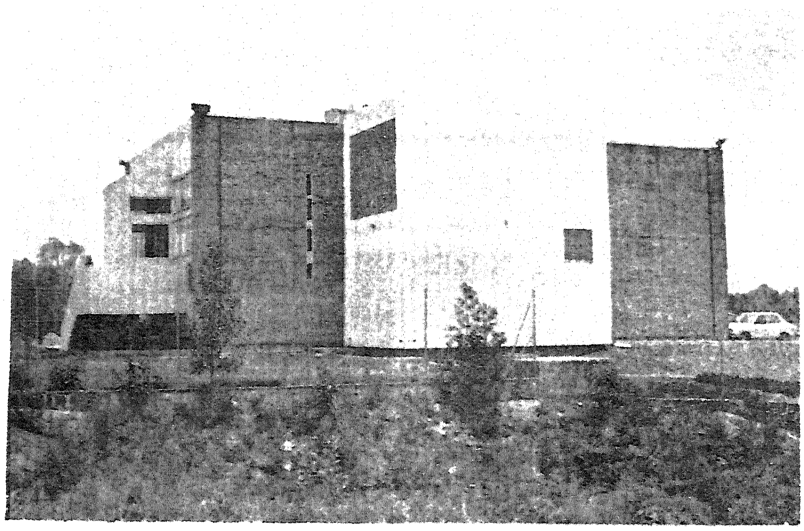

Fig 1. Dynamics laboratory

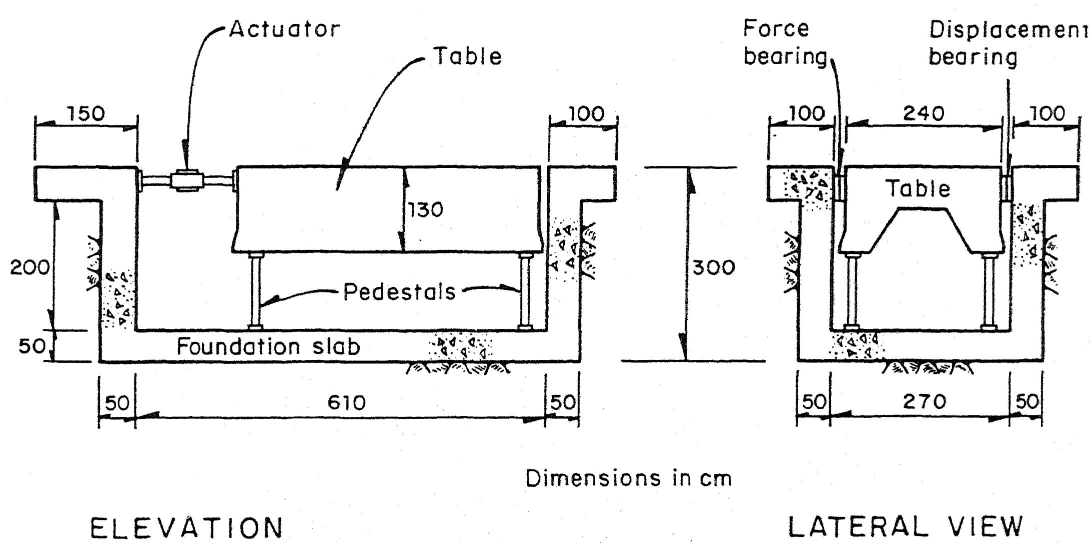

Fig 2. Cross-sectional view of shaking table and foundation

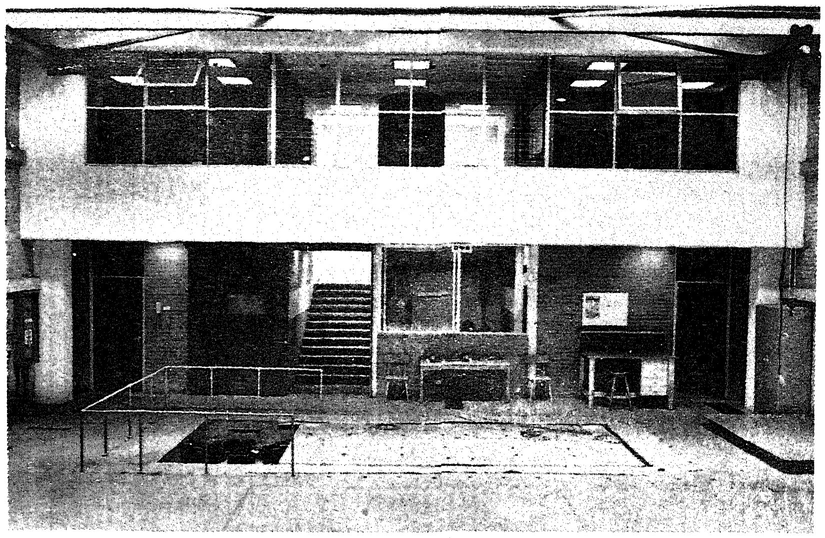

Fig 3. Shaking table

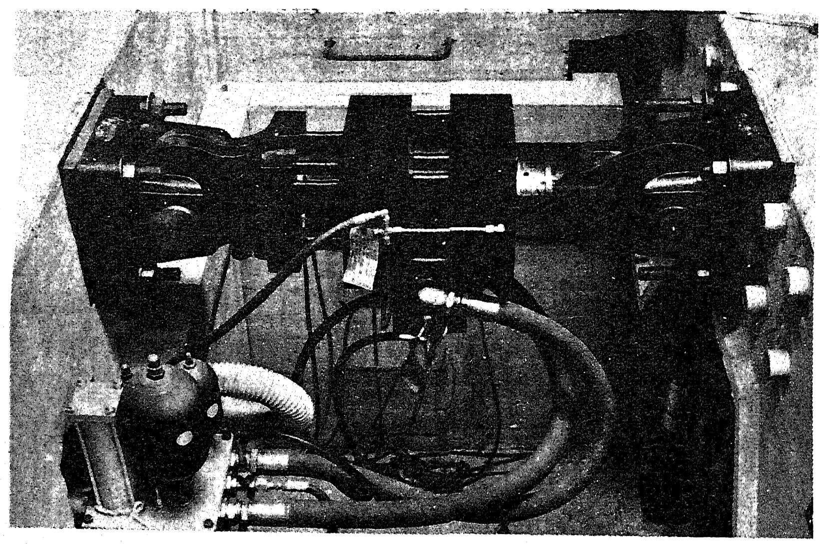

Fig 4. Actuator and pedestal

DISCUSSION

A. Ravara (Portugal)

When is the new laboratory supposed to start in operation and which are the main topics of research that are going to be undertaken in it ?

Author's Closure

With regard to the question of Mr. Ravara, we wish to state that the dynamics laboratory has been operating since April, 1977. The research program to be carried out includes the following topics:

Structures

The possibility of studying prototypes of structures that do not exceed the maximum height of the laboratory building (7.5 m) is being considered; for example, its dynamic behaviour for different arrays of columns, girders and joints with different types of shear walls, different bracing and floor systems, materials, etc.

Tests on special structures such as towers, liquid tanks (to complement analytical studies an hydrodynamic distribution of pressures), and massive supports for turbogenerators will also be performed.

Presently (Jul. 1977), an investigation is being carried out to determine experimentally the dynamic characteristics of a device to limit the seismic actions on high rise buildings.

Soils

The conditions under which soils (as part of foundations or as construction materials) loose a significant part of their resistance leading to failures induced by earthquakes are not fully known thus constituting a fertile field for research in Earthquake Engineering. Our program in this topic comprises:

a) Determination of dynamic soil properties. Testing of large soil samples with the purpose of reducing distortions due to boundary conditions as is the case of tests on small samples.

b) Soil liquefaction. To perform tests of sand liquefaction, the simple shear apparatus, AL-72, designed at UNAM (ref. 2), will be used. It will permit the testing, with the use of the shaking table, of sand samples (3ocm x 60 cm x 90 cm) of loose and saturated sand under undrained conditions and subjected to simple shear. The dimension of the sample allow the location of instruments in its interior that will enable us to know the evolution of the pore pressures that give rise to liquefaction.

c) Slope Stability

Dams

The purpose is to continue the development of analytical and experimental methods to improve the present knowledge of the dynamic behaviour of rock-fill dams. An artificial material especially developed (ref 1) will be used to build the models.