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CONSTRUCTION OF A 3-D FULL-SCALE EARTHQUAKE TESTING FACILITY

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ABSTRACT: After the great Hanshin-Awaji earthquake disasetr, the National Research Institute for Earth Science and Disaster Prevention (NIED) and the Science and Technology Agency of the Japanese Government (STA) planned to build a three-dimensional, full-scale, earthquake-testing facility (E-Defense) as one of the core research facilities for earthquake disaster prevention. It is hoped to be able to carry large-scale structures and to simulate the process of dynamic collapse using three-dimensional, strong earthquake records. For this purpose, the NIED has developed large actuators and related components from 1995 and completed them in 1998. After that, the NIED and the STA began the design and construction of the new facility in the fiscal year of 1998, and now, the construction work is in final stage at Miki City, near Kobe, Japan. It is scheduled to complete by the beginning of 2005. In this paper, the basic performance and features of this new facility and the outline of recent construction work are summarized.

Key Words: 3-D shaking table, Full-scale seismic test, Great Hanshin-Awaji earthquake disaster, Earthquake disaster prevention

BASIC SPECIFICATIONS

In order to determine basic specifications, various discussions in some special committees organized by the STA were conducted. Ground motions during the Hyogo-Ken-Nanbu earthquake and other strong motions recorded or predicted were considered in the discussions (Katayama et al. 1998). Table 1 shows the basic specifications of the new facility under construction. Figure 1 shows the performance limit of the shaking table for three levels of test weight. These curves can be applied only to the sinusoidal excitations. A horizontal excitation of *ca.* 1.7g can be applied to light structures, such as a wooden house or various types of equipment and piping. In the vertical direction, a maximum acceleration of 1.7 g can be available even in the case of a 600 ton test mass. This is because the total power of the vertical actuators has been specified so as to get a sufficient value of an allowable

Table 1 Basic specifications of the shaking table

	Horizontal (X and Y)	Vertical (Z)
Table size	20m x 15m	
Maximum test mass	1,200tonf	
Driven direction	X,Y,Z translations and rotations (6 degree of freedom)	
Drive mechanism	Accumulator charge / Electric-Hydraulic Servo Control	
Maximum displacement	200cm p-p	100cm p-p
Maximum velocity	200cm/s	70cm/s
Maximum acceleration (at maximum test mass)	0.9G	1.5G
Max. overturnning moment	>15,000tonf.m (at Z:1G excitation)	
Max. yawing moment	>4,000tonf.m (at max horizontal acceleration)	
Max. rotation	2.5 degree (around X, Y, or Z)	
Frequency range	0-15Hz(with accuracy), 15-30Hz (possible to be excited)	
Wave distorsion	<15% (in useful domain of frequency and amplitude)	
Control	Real time digital control Basic (TVC etc.) Advanced (High speed input compensation etc.)	
Measurement	896ch for test specimen 64ch for table control (selected of 420 signals) A/D normal(864chs) : resolution 24bit, sampling 2kHz(max) high speed(32chs): resolution 16bit, sampling 1MHz	

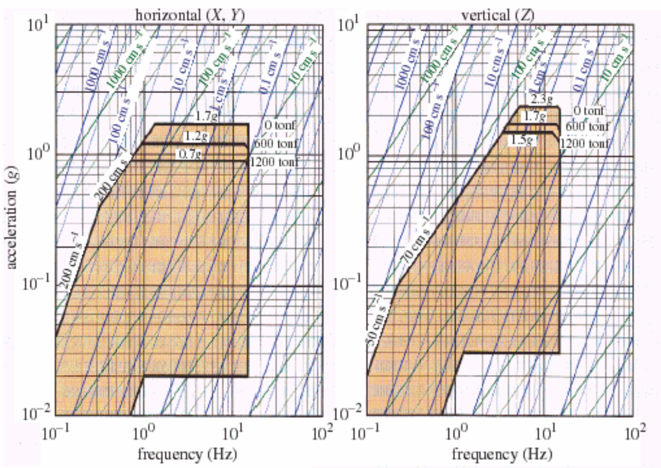

Fig.1 Limit performance of shaking table

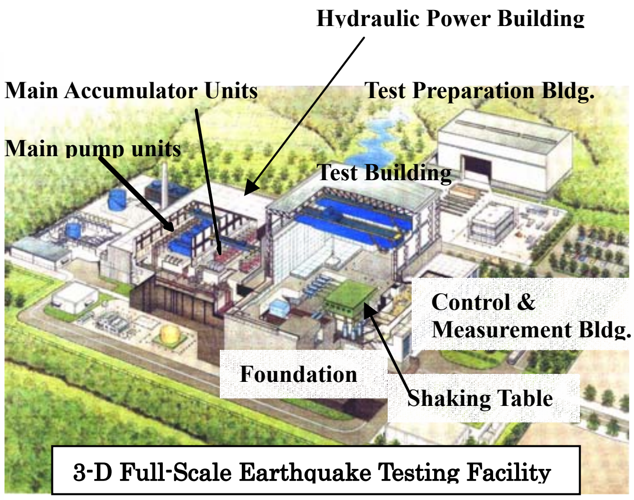

Fig. 2 A layout of the facility

overturning moment. Considering the purpose of the facility, performance of velocity and displacement will be emphasized more than that of acceleration. The maximum horizontal acceleration of 0.9 g was decided on by considering that the facility mainly aims at reproduction of ground or base motion of structure. In addition, high velocity and large displacement are useful for the floor response of high-rise buildings and other flexible structures such as isolated buildings. Figure 2 shows the layout of the facility.

FEATURES OF THE FACILITY

One of the unique features of the table is its rectangular shape, which is different from the other large shaking tables of NIED(Tsukuba, 1-dimensional) and NUPEC(Tadotsu, 2-dimensional). Some test structures may have a square or axisymmetric shape, but many others may have a rectangular shape, e.g. building, bridge, soil boxes and pipelines. In order to use the table surface area effectively under the test weight limit, a rectangular-shaped table is desirable in most vibration tests. On the other hand, the performance in the two horizontal directions(X and Y) has been designed to be the same, because test structures such as buildings and soil layers require the maximum performance in the short or the long directions of the table according to weakness of test structure.

As for the control system, in addition to the traditional offline input compensation method, some online methods will be planned to be installed. Really, two levels of control method will be installed. One is the most basic control system to be installed initially, which has the reliability and stability in any condition of table and test specimen. General types of seismic test can be usually performed by use of the basic control system. The second level control method, which is expected to better improve shaking performance, will be optionally additional to the basic control system. The advanced control methods are basically a set of control software and some of which are under developing (Sato et al. 2001, Okuda et al, 2001, Shimizu et al. 2003). They will be used for special request of researcher if required. The advanced control methods can be selected in compliance with the requirement of experimenter.

The whole number of measurement channels for test structure is planned to be 896 finally. Additionally, 64 channels of dynamic data from the motion of shaking table and actuators are also available to estimate table performance. All measurement channels of test specimen are recorded by 15-blocks of sub systems corresponding to signal amplifier units with A/D converter which are planned to be installed inside of the shaking table. All digital format test data are transmitted to the data storage in the measurement room through optical fiber.

CONSTRUCTION WORK OF THE FACILITY

The facility is positioned at Miki city in the north part from Kobe city. The construction work of the facility began in the fiscal year of 1998 and will end at the beginning of 2005. The new facility will start to operate 10 years after the great Hanshin-Awaji earthquake disaster of 1995. Now, building construction and machine installation work were finished, and static and dynamic performance of each single actuator, and welding of the shaking table on site are in progress.

Fig.3 General view of installation of

Fig.4 Shaking table (welding of 32 blocks

actuators (X:5, Y:5, Z:14) was almost finished, Jan 2004)

Figure 3 and 4 show the installed 24 hydraulic actuators in the foundation, the shaking table in welding, respectively. All mechanical components will be finally assembled and connected by the mid of this year and the general operation test will be conducted after that. These construction works and results of related technical development are already reported (Katayama et al. 1998, Ogawa et al. 1999 and 2000, Ohtani et al. 2001).

SYSTEM PERFORMANCE TEST

The general performance test will be conducted with two stages. In the first stage test, no test structure is set on the shaking table. This test mainly consists of two parts as follows.

1) Performance test to assure the basic specification such as maximum acceleration.
2) Control performance test to assure the simulation of earthquake motion including random and sinusoidal excitations. In this test, some advanced control methods will be applied in addition to basic control method.

A time schedule and contents of the performance test is shown in Table 2. This first stage test does not fully guarantee the control performance in the real seismic test condition. Then the second stage performance test with a test structure on the shaking table is under preparation. In this test, control performance against large overturning moment and resonance effect of test structure will be investigated, and the system total performance will be tuned for better control condition to apply to experiments of use plan after 2005 (Sato and Inoue 2003).

Table 2 Outline of the system performance test

Item	2004	2005	2006	Main Contents
Performance test (Without load on the table)				1) Basic performance test •Max. displacement, velocity, acceleration and rotational performance test •Velocity duration performance test •Overturning and yawing test •Limit performance test in frequency and amplitude range 2) Control performance test •Static accuracy test •Frequency characteristics and stability test •Cross-talk control performance test •Sinusoidal wave accuracy test •Earthquake wave simulation performance 3) Relational test •Foundation vibration measurement •Table stress/strain measurement
Performance test (With structure on the table)				Control performance test against overturning moment etc. by test specimen (details are under planning).
Apply to experiments				

CONCLUSIONS

Construction work of the new three-dimensional, full-scale, earthquake-testing facility is now progressing to final stage. Some performance tests will be soon conducted and the authors expect to achieve the useful capability for seismic test.

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