

PROJECT ON 3-D FULL-SCALE EARTHQUAKE TESTING FACILITY (THE THIRD REPORT)

by

Keiichi OHTANI¹⁾, Nobuyuki OGAWA²⁾, Tsuneo KATAYAMA³⁾, Heki SHIBATA⁴⁾

ABSTRACT

Considering the lessons learnt from Hanshin-Awaji Earthquake, NIED plan to construct “E-Defense”, which will be able to simulate the processes of destruction of structures under the condition of real strong earthquake motions. The basic performance of “E-Defense” are maximum lording capacity 1,200 tons, maximum velocity 200 cm/s and maximum displacement +/- 1 m for horizontal excitation and maximum velocity 70 cm/s, maximum displacement +/- 50 cm for vertical excitation to realize destructive ground motion. The construction work of “E-Defense” has been begun at early 2000, and will be completed at the beginning of 2005. We are conducting the construction works of the facility at the Miki-city, and the manufacturing of actuators, oil-pressure supply system and other major part of shaking table at the MHI. “E-Defense” is the very large scale and high performance testing facility in the world. “E-Defense” should be operated the international common use. For the international collaboration and the dissemination of research results, E-Defense Network (“ED-Net”) will also construct until the completion of “E-Defense”. We hope that “E-Defense” and ED-Net will be situated to one of the cooperative research organization for the earthquake disaster mitigation in the world.

KEY WORDS:

Failure mechanism of structures
Full Scale Testing
International Common Use

3-D Shaking Table

Network of Earthquake Research

1. INTRODUCTION

The Hanshin-Awaji Earthquake (Hogoken-Nambu Earthquake, January 17, 1995) clearly demonstrated that the occurrence of very strong ground motion in the area near to the seismic fault is capable of causing severe structural damage beyond general estimation. The destructive earthquake occurred in the worldwide in the recent years, such as Northridge earthquake (1994), Umbria-Marche earthquake (1997), Kocaeli earthquake (1999), Ji-ji earthquake (1999), El Salvador earthquake (2000), Gujarat earthquake (2001) and so on.

In order to reduce the hazards associated with large earthquakes, it is essential to improve the reliability of earthquake resistance estimations and reinforcement methods in the construction of urban and major structures. For this purpose, failure mechanisms and collapse processes of various kinds of full-scale structures must be investigated. Many types of experimental apparatus have been used for such investigations, and some of them have as large a size as possible to alleviate any difficulties arising from limitation

-
1) Project Director, 3-D Full-Scale Earthquake Testing Facility (E-Defense), National Research Institute for Earth Science and Disaster Prevention (NIED), Tsukuba, Japan

2) Project Sub-Director, E-Defense, NIRD, Japan

3) President, NIED, Japan

4) Visiting Research Fellow, NIED, Japan

of the model. Considering the lessons learnt from recent earthquake disasters, the National Research Institute for Earth Science and Disaster Prevention (NIED) planned to build a new three-dimensional, full-scale, earthquake testing facility, which can carry large-size soil and structure models and reproduce the processes of structural failure. This facility is expected to become a powerful tool for international collaboration in earthquake engineering research. It also requires international cooperation to successfully complete the facility and to use it effectively for engineering purposes.

Following the technical developments and surveys in earthquake engineering and related fields, the NIED began the design and construction of this new facility in the Japanese fiscal year of 1998.

We already reported twice for the Joint Meeting of Wind and Seismic Effects, UJNR. In the first report (30UJNR), we described the introduction of project on E-Defense. In the second report (34UJNR), we summarized the construction plan and Earthquake Engineering Network (EE-Net), which is the tool for ensure of the international collaboration and the dissemination of research results. The name of EE-Net was changed to E-Defense Network (ED-Net), because new name can explain more suitable to our network.

This paper is the progress report of our project, such as construction and installation works, control and measurement systems and management mechanism.

2. E-DEFENSE (3-D FULL-SCALE EARTHQUAKE TESTING FACILITY)

Based on the lessons learnt from Hanshin-Awaji earthquake, the Minister of State for Science and Technology was inquired to the Council for Aeronautics, Electronics and Other Advanced Technology, which is the one inquire organization of the Minister, for the discussion of the effective

arrangement of research bases for earthquake disaster mitigation at March 29, 1996. The Council was reported to the Minister at September 3, 1997.

The report was clearly pointed out the arrangement of large-scale three-dimensional earthquake simulator facility as the core facility of research bases for earthquake disaster mitigation.

NIED initiated the project on the large-scale three-dimensional earthquake simulator facility just after the occurrence of Hanshin-Awaji earthquake. The research and development for core technology for this facility (E-Defense) was started on 1995. The fundamental concepts of this project based on the report by the council.

The E-Defense will construct as the core facility of the research bases for earthquake disaster mitigation. Therefore, we need to clear the positions of the E-Defense.

- 1) Position of earthquake simulator for the main element of development of the "Time-Space Domain Simulation System for Earthquake Disaster.)
- 2) Position of the clearly understanding of failure mechanism of structures.
- 3) Position of the response mechanism for the request from major subject of earthquake engineering.

The importance of promoting the strengthening and rationalization of earthquake-proof structural design is just one of the lessons from Hanshin-Awaji earthquake. Because earthquake vibrations involve three-dimensional movement, it is necessary to set up a three-dimensional earthquake simulator facility to accurately reproduce earthquake motions. To perform tests on real-size objects or large-scale models of test structures and foundations, it is desirable to have the large-scale three-dimensional shaking table. If large-scale 3-dimensional shaking table is available, tests could be performed to shed new light on the mechanism of dynamic failure using real-size structures. If a stage reached whereby

design based on such discovery can be performed, this will contribute immensely to reducing earthquake disaster.

The main specification of E-Defense is shown in Table 1. The actuator performance for horizontal and vertical axes is shown in Fig. 1.

Table 1. Main Specification of E-Defense

Payload	12MN(1200tonf)	
Size	20m × 15m	
Driving Type	Accumulator Charge Electro-Hydraulic Servo Control	
Shaking Direction	X·Y - Horizontal	Z-Vertical
Maximum Acceleration (at Maximum Loading)	>900cm/s ²	>1,500cm/s ²
Maximum Velocity	200cm/s	70cm/s
Maximum Displacement	± 100cm	± 50cm
Maximum Allowable Moment	Overtuning Moment	Yawing Moment
	150MN·m	40MN·m

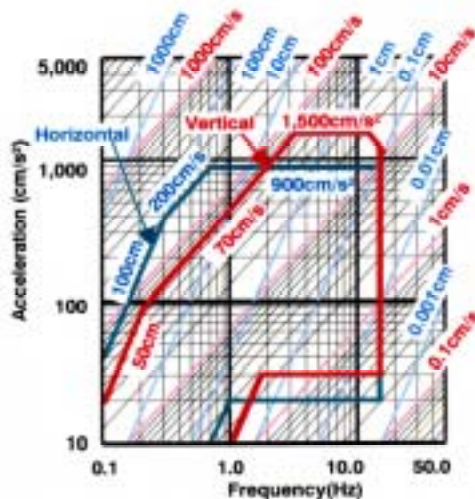


Fig. 1. Limit Performance of E-Defense

3. CONSTRUCTION AND MANUFACTURING OF E-DEFENSE

NIED have commenced the development work of shaking mechanism with very large size of hydraulic actuators in fiscal year 1995 and completed performance tests successfully in 1998. Following the above technical development and surveys in earthquake engineering and related fields, NIED have began the design and construction of E-Defense in 1998.

The construction work has been begun in 1998 and will be completed at the beginning of 2005. The new facility will start to operate at the 10 years after the Hanshin-Awaji earthquake. The E-Defense is constructed in “Miki Earthquake Disaster Memorial Park (tentative name)”, which is being constructed in Miki city, on the north of Kobe city. The construction of shaking table foundation was started at the construction site in January 2000.

The manufacturing of testing equipments, such as actuators, 3-dimensional link joint, oil power pump unit, accumulator unit and so on, were started in 1998.

We will construct several buildings, such as Experimental Building, Operation Building, Hydraulic Unit Building, Preparation Building and so on. The 3-dimensional shaking table will be installed in the experimental building. Hydraulic oil will be supplied to shaking table by pipelines via underground culvert. The reaction foundation (shaking table foundation) has weight of about 2 GN (200,000 tonf) and set to the bedrock directly.

Following the construction of shaking table foundation, we construct the experimental building and other buildings. The experimental building is 60 m X 85 m in plan and 45 m height and has tow sets of 400 tons crane. For the construction of large space frame, we developed and applied new construction methods, such as the sliding construction method for roof members using permanent traveling crane structure, and the large panel method of external wall by steel frame and sandwiches panel. Fig. 2 and 3 show the construction views of sliding construction method and large panel method, respectively.

For the construction of hydraulic unit building, we also developed and applied new method, which is the robot painting method of external wall. Fig. 4 shows the robot painting method.



Fig. 2 Sliding Construction Method



Fig. 3 Large Panel Method



Fig. 4 Robot Painting Method

The manufacturing of the testing equipment, such as actuators, 3-dimensional link joint, oil power pump unit, accumulator unit and so on, were also started in 1998. By the condition of construction site, where is located at the hill area, the weight and length of manufactured unit are limited some size by the condition of transportation. The set-up working was done at the site.

The installation of piping system, actuators, pumping units and accumulator units were started in 2000. Figs. 5 – 8 are shown the installed

condition of actuators, pumping units, accumulator units and the recent construction condition of buildings, respectively.



Fig. 5 Installation of Actuators



Fig. 6 Main Hydraulic Pump Units



Fig. 7 Main Accumulator Units



Fig. 8 Recent Construction Condition

4. CONTROL AND MEASURING SYSTEMS

The control system of shaking table and measuring system are key functions of the facility. We are currently arranging these systems.

The control model is composed 2 step systems, basic control system and Application control system. The basic control system is used for the safety control of shaking table, which is composed TVC (Three Variable Control) technique. Application control system is used for the more accuracy control of shaking table. The researcher can insert the own control technique to the control system. Fig. 9 shows the block diagram of control system.

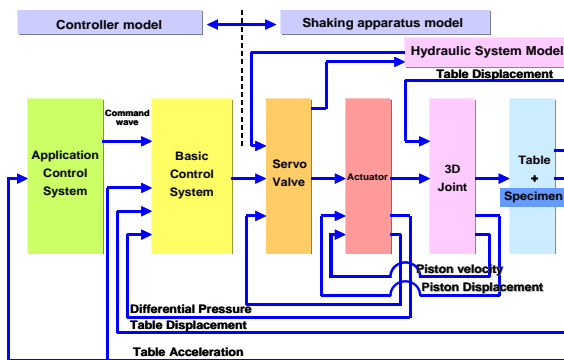


Fig. 9 Block Diagram of Control System

The E-Defense is the large scale testing facility, therefore, the researcher, who use this facility, want get a lot of data during test. We will install

960 measuring channels. We have 440 channels of the sensor for control signal. The 64 channels within these 440 channels are able to record the measuring system. The 896 channels of the sensor for measurement are installed for the research purpose. Fig. 10 shows the block diagram of measuring system.

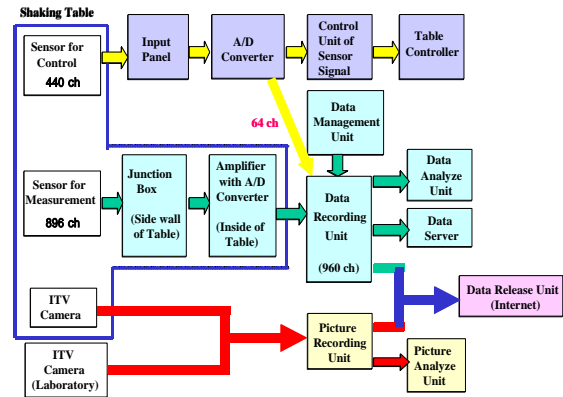


Fig. 10 Measuring System

5. MANAGEMENT MECHANISM

For the management of E-Defense, we are thinking about following management mechanism. We will establish the Hyogo branch (tentative name) for the operation of facility and conducting the research works. But, by the limitation of number of regular staffs, we will establish the Supporting Consortium, such as outsourcing mechanism. This Supporting Consortium is functioned to conduct the smoothly operation of facility cooperate with the staffs of Hyogo branch. We established one council and one committee for more effective management and operation of facility.

The Management Council is organized by the representatives from government, academic and private sectors. Dr. S. Ito, President, Research Institute for Urban Disaster Mitigation, is chaired the Council. 18 members were nominated. This council will discuss the medium and long term management plan and more effective management of facility.

The Utilization Committee is organized by the active researchers from various fields of earthquake engineering. Prof. K. Kawashima, Tokyo Institute of Technology is chaired this committee. 19 members were nominated. This committee will discuss the research plan and research results by using this facility.

Fig. 11 shows the Management mechanism.

Fig. 11 Management Mechanism

6. EARTHQUAKE ENGINEERING COLLABORATION

E-Defense should be operated the international common use. To ensure the international common use and disseminate the test results, we will construct and install the E-Defense Network (ED-Net).

The ED-Net has tow major functions: The one is the connection tool between E-Defense in Miki and the Super Computer in Tsukuba. The other one is the connection tool between NIED and the other organization, such as research institute, university, private sector and so on. This function is not only limited to domestic, but also international manner.

We will install the tele-observation and tele-discussion capabilities, but not install the tele-operation function. Because, conducting of shaking table test, especially failure test, has very delicate and dangerous factors. Therefore, the operation of shaking table will limit by the shaking table administrator, who is the specialist

of operation. Figure 12 shows the schematic image of ED-Net.



Fig. 12 Schematic Image of ED-Net

7. CONCLUDING REMARKS

Based on the lessons learnt from Hanshin-Awaji earthquake, we, NIED, need more research to understand the failure mechanism of different kind of structures during earthquake. For this research needs, we began the construction project of E-Defense (3-D Full-Scale Earthquake Testing Facility) and ED-Net (E-Defense Network). After completion, these tools will be perfectly opened to international use.

We strongly hope that these tools are contributed to the dramatic progress of the earthquake engineering research, especially the understanding of structural failure mechanism, the progress of the earthquake resistant design of structures and the evaluation/reevaluation of structural performance during earthquake, by the coordination and collaboration research works in the worldwide bases.

ACKOWLEGEMNTS

For the progress of Project “E-Defense”, NIED established the Technical Advisory Committee (Chairman: Prof. H. Sato, University of Chuo, Committee members: 10 Professors). The authors acknowledge the Committee members for the support and kindly advice.

REFERENCES

Ohtani, K, Katayama, T, Shibata, H. (1998) “Project on

- 3-D Full-Scale Earthquake Testing Facility – First Report-“, *30UJNR*
- Ohtani, K, Katayama, T, Shibata, H. (2002) “Project on 3-D Full-Scale Earthquake Testing Facility – The Second Report-“, *34UJNR*
- Ogawa, N, Ohtani, K, Katayama, T, Shibata, H. (1999) “World’s Largest Shaking Table Takes Shapes in Japan – A Summary of Construction Plan and Technical Development-“, *SmiRT 15*
- Ohtani, K, Ogawa, N, Katayama, T, Shibata, H, Nakagawa, O, Ohtomo, T. (2001) “World’s Largest Shaking Table Takes Shapes in Japan (The 2nd Report)”, *SmiRT 16*
- Ohtani, K. (2001) “Tools for Seismic Safety Evaluation of Structures”, *NEA/CSNI/R(2001)13/VOL3*
- Ohtani, K, Ogawa, N, Katayama, T, Shibata, H. (2002) “3-D Full-Scale Earthquake Testing Facility and Earthquake Engineering Network”, *3WCSC*
- Ohtani, K, Ogawa, N, Katayama, T, Shibata, H, “Project “E-Defense” –Introduction of E-Defense-“, *2003PCEE*
- Harada, T, Koike, A, Uchida, M, Ohtani, K, Ogawa, N, ”Project “E-Defense” –Technical Development of Mechanical Components-“, *2003PCEE*
- Rood, O.E, Ohtani, K, Yoshida, E, “Project “E=Defense” –Control System Architecture-, *2003PCEE*