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

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#### ABSTRACT

The Hanshin-Awaji 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. It has emphasized the importance of earthquake engineering research into why and how structures real earthquake collapse in conditions. Considering the lessons learnt from recent earthquake disasters, NIED plan to construct a "3-D Full-Scale Earthquake Testing Facility ("E-Defense" is the nickname of this facility)", which will be able to simulate the processes of destruction of structures under the condition of real strong earthquake motions.

The basic performances of "E-Defense" are maximum lording capacity 1,200 tons, maximum velocity 200 cm/s and maximum displacement 2m p-p for horizontal excitation and maximum velocity 70 cm/s, maximum displacement 1m p-p for vertical excitation to realize destructive ground motion. The construction work of "E-Defense" has began at early 2000, five year after the Hanshin-Awaji Earthquake and will be completed at the beginning of 2005, ten years after that Earthquake. Now, we are conducting the construction works of the facility at the Miki-city, near Kobe-city, and the manufacturing of actuators, oil-pressure supply system and other major parts of shaking table at the Mitsubishi Heavy Industry Co.

"E-Defense" is the very large scale and high performance testing facility in the world. Therefore, many researchers, which are belonging

only Japanese but also worldwide not organizations, can use this facility for their researches. "E-Defense" should be operated the international common use. For the international collaboration and the dissemination of research results (including test data). Earthquake Engineering Network ("EE-net") will also construct until the completion of "E-Defense". EE-net will connect, through a high performance Internet, distributed major earthquake engineering research organization.

We consider that the researchers together from worldwide and research projects will determine and evaluate by the International Committee. We hope that "E-Defense" and EE-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

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

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The Hanshin-Awaji Earthquake (Hyogoken-Nanbu 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 Kocaeli earthquake (1999), (1997),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 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. also requires It 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. This paper summarizes 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.

# 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.

- 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



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.

Figure 2 shows the drawing bird eye view of E-Defense. We will construct several buildings, such as laboratory building, measurement and control building, hydraulic oil unit building, preparation building and so on. The 3-dimensional shaking table will be installed in the laboratory building. Hydraulic oil will be supplied to shaking table by pipelines via underground culvert. The reaction foundation (shaking table foundation) has weight of about 2GN (200,000 tonf) and set to the bedrock directly.

The construction work has been began 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 The construction of shaking table Kobe city. foundation was started at the construction site in January 2000. Figure 3 shows the aerial photograph of the site before the construction work. Figure 4 shows the scene of the first concrete casting for the foundation. The D51 (diameter 51 mm) reinforcing bars used for the foundation, such as the foundation for Nuclear Power Plant. Figure 5 is the recent construction condition.

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. By the construction of

manufactured unit are limited some size by the condition of transportation. The setup working will be done at the site. Figure 6 shows the set-upped actuator in the preparation building.

# 4. EARTHQUAKE ENGINEERING NETWORK

The report by the Council was strongly suggested that E-Defense should be operated the international common use. It is important to arrange the utilizing structures, equipment and support section for outside users. To ensure the international common use and disseminate the test results, we will construct and install the Earthquake Engineering Network (EE-Net).

The EE-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 7 shows the schematic image of EE-Net, and Table 2

Shows the security control system for different kind of users.

## **5. 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 EE-Net (Earthquake Engineering 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 evaluation/reevaluation the of structural performance during earthquake, by the coordination and collaboration research works in the worldwide bases.

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Fig. 2 Layout of E-Defense



Fig. 3 Construction Site at Miki, near Kobe (January 17, 2000)



Fig. 4 First Concrete Casting for Shaking Table Foundation (June 20. 200)



Fig. 5 Recent Construction Condition (April 18, 2002)



Fig. 6 Set-upped Horizontal Actuator



Fig. 7 Schematic Images of EE-Net

Table	2	Security	Control	for	Users

	Shaking Lable operation	Control Program upload	Execute exchanation simulation	TV Conference Participation	Access to test data
Shaking table administrator	0	0	0	0	0
Shaking table User (at Miki)	×	0	0	0	0
Methematical amulator administrator	X	0	0	0	0
Mathematical simulator user (at Miki)	×	0	0	0	0
Mathematical simulator user (at TSUKUBA)	×	0	0	0	0
Network administrator	X	-		0	0
Network User (at Miki)	×	1	-	0	0
Network User (at TSUKUBA)	×	-	4	0	0
RABnet User	X	0	0	0	0
US NEES User	X	0	0	0	0
EU JRC User	X	0	0	0	0
Internet User	X	×	X	X	O jimint access