CONSTRUCTION OF E-DEFENSE (3-D FULL-SCALE EARTHQUAKE TESTING FACILITY)

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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 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 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, assembling and installing of actuators, oil-pressure supply system and other major parts of shaking table by the Mitsubishi Heavy Industry.

"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". ED-net will connect, through a high performance Internet, distributed major earthquake engineering research organizations. 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.

1. INTRODUCTION

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 (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 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. This paper summarize the construction plan and E-Defense (ED-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.

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 limit performance for horizontal and vertical axes is shown in Fig. 1.

Table 1: Main Specification of E-Defense

3-D Full-Scale Earthquake Testing Facility		
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	Overturning Momet	Yawing Moment
	150MN·m	40MN·m

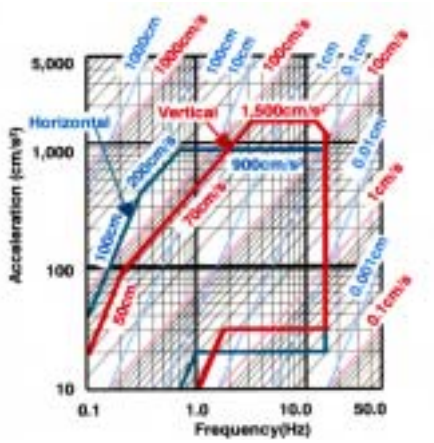

Figure 1: Limit Performance

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 2 GN (200,000 tonf) and set to the bedrock directly.

Figure 2: Layout of E-Defense

The construction work has 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 Kobe city. The construction of shaking table foundation was started at the construction site in January 2000. Figure 3 shows the aerial photograph of the site before the construction work.

Figure 3: Construction Site (January 17, 2000)

Figure 4 shows the scene of the first concrete casting for the foundation. The D51 (diameter 51 mm) reinforcing bars were used for the foundation, such as the foundation for Nuclear Power Plant. Figure 5 is the recent construction condition.

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.

Figure 4: First Concrete Casting (June 20, 2000)

Figure 5: Recent Construction Condition

The installation of piping system, actuators, pumping units and accumulator units were started in 2000. Figs. 6– 8 are shown the installed condition of actuators, pumping units, accumulator units and the recent construction condition of buildings, respectively.

Figure 6: Assembling of Actuator

Figure 7: Installation of V-Actuators

Figure 8: Installation of H-Actuator

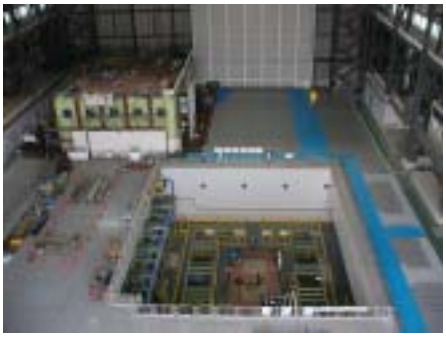

Figure 9: Recent Condition

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. 10 shows the block diagram of control system.

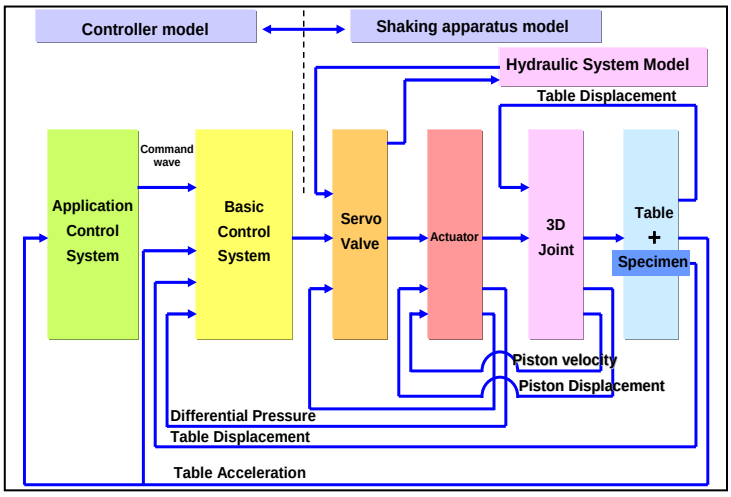

Figure 10: Block Diagram of Control System

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. 11 shows the block diagram of measuring system.

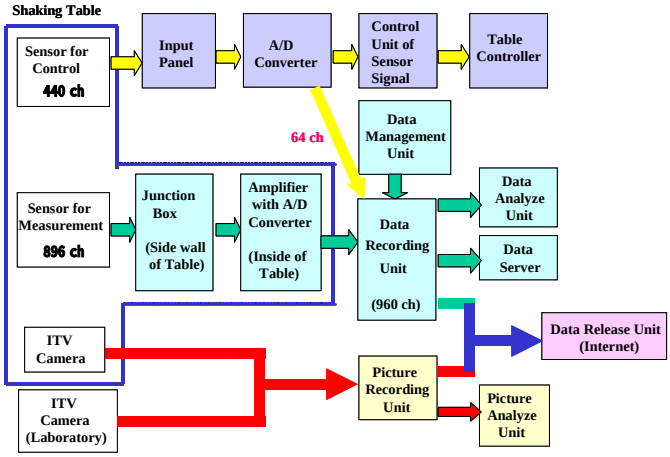

Figure 11: Measuring System of E-Defense

5. MANAGEMENT MECHANIZM

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.

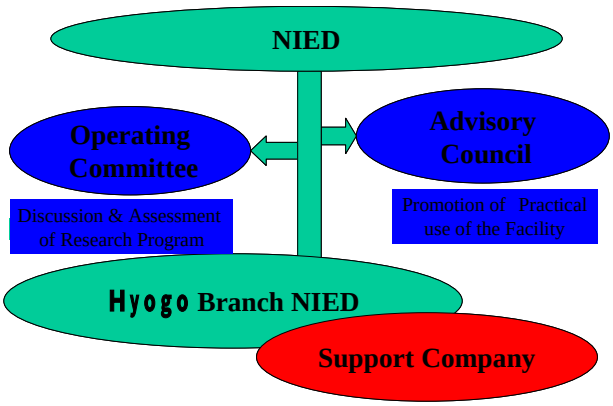

Figure 12: Organization for Operation of E-Defense

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. 12 shows the 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 13 shows the schematic image of ED-Net.

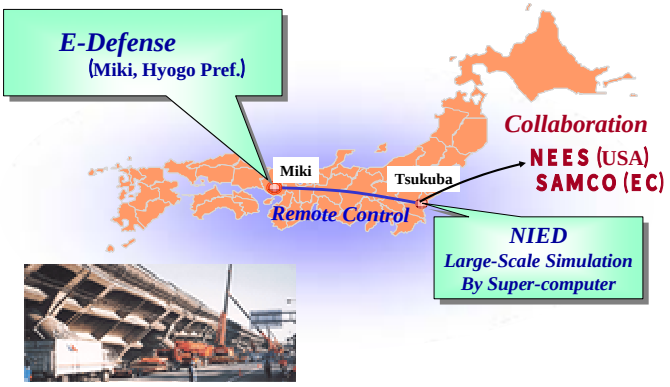

Figure 13: Schematic Image of ED-Net

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.