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GENERAL FRAME WORK OF RESARCH TOPICS UTILIZING THE 3-D FULL-SCALE EARTHQUAKE TESTING FACILITY

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ABSTRACT: National research Institute for Earth science and Disaster prevention is constructing the world's largest 3-D full-scale shake table which is nicknamed as "E-Defense". In order to resolve several subjects for the utilization of E-Defense, NIED investigates the themes as follows, 1) Establishment of utilization and wide area network systems, 2) Development of 3-D ground motion database and a numerical simulation system for the shake table, and 3) Test and analysis of reinforced concrete structures, soil-pile-structure systems and wooden structures for using E-Defense.

Key Words: 3-D full-scale shake table, reinforced concrete structures, soil-pile-structure systems, wooden structures, numerical simulation system for the shake table, 3-D ground motion database

INTRODUCTION

National research Institute for Earth science and Disaster prevention in Japan (NIED) is constructing the so-called E-Defense or the world's largest three-dimensional (3-D) full-scale shake table in Miki city near Kobe. General view of E-Defense is shown in Photo 1. Shake table shown in Fig. 1 is located in an experiment building and has the basic specifications shown in Table 1. The summary and the construction of this facility were reported already by Ogawa (1999) and Ohtani (2003).

Photo 1 General view of E-Defense

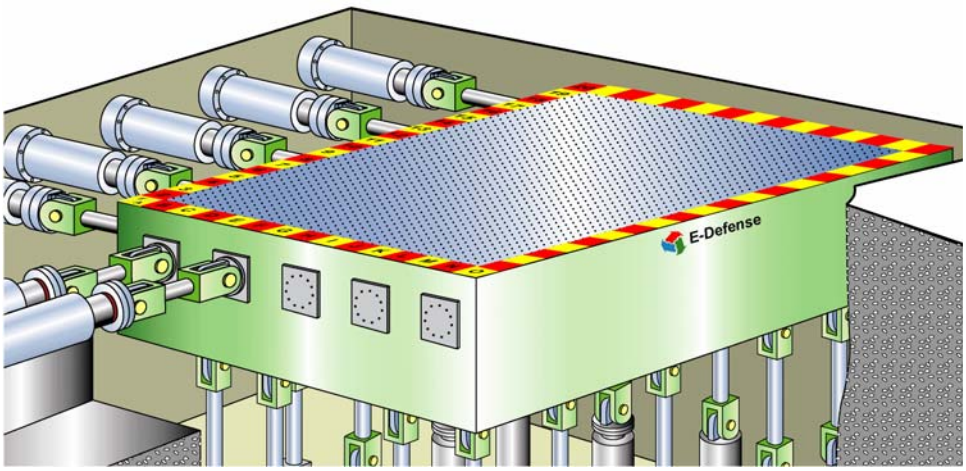

Figure 1 Overall image of the largest shake table

Table 1: E-Defense specifications

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

This facility will be used to reproduce dynamic behavior of full-scale structure models subjected to actual huge earthquakes. Consequently, it will greatly contribute in improving the seismic performance and design of structures. This paper describes the general framework of the research topics utilizing E-Defense.

OUTLINE OF THE PROJECT

For considering how to use E-Defense most effectively, there are many research subjects which NIED should make clear before the operation of the facility becomes possible. In order to contribute in improving the seismic performance and design of structures by utilizing E-Defense, NIED conducted a new research project, tilted as “No.2 significant improvement of seismic performance of structures” in a special project for earthquake disaster mitigation in urban areas. The project is sponsored by the ministry of education, culture, sports, science and technology in Japan (MEXT) and has been started from September 2002.

This project contains six main research topics as presented in Table 2. This huge amount of research work became possible by close collaboration of dozens of domestic research centers, universities, independent administrative institutions and private companies. The research organizations which are involved in this collaborative research are also included in Table 2.

Currently, we are heavily involved in preparation of the practical plans for full-scale shake table test models of reinforced concrete structures, soil-pile-structure systems and wooden structures.

The duration of this project is for about five years, which has been started from September, 2002 and will end in March, 2007. The first half of the total period is the preparation time to provide the requirements for the experiment and research related to the utilization of E-Defense. The second half

is the period to perform experiments and research using E-Defense to improve the seismic performance and design of structures.

Table 2: Research topics and the related organizations

Research topics	Research organizations
Establishment of utilization and wide area network systems	NIED
Test and analysis of reinforced concrete structures	NIED, The University of Tokyo, Toyohashi University of Technology, BRI, Kyoto University, KAJIMA, SHIMIZU
Test and analysis of soil-pile-structure systems	NIED, Tokyo Institute of Technology, NIRE, PWRI, KAJIMA, TAISEI, TAKENAKA, Tohoku University, KISO-JIBAN CONSULTANTS, The Japanese Geotechnical Society
Test and analysis of conventional wooden structures	NIED, The University of Tokyo, BRI, Kyoto University, FFPRI , NIHON SYSTEM SEKKEI,
Development of an advanced control system for E-Defense	NIED
Development of a 3-D ground motion database	NIED, The University of Tokyo, Kyoto University

BRI: Building Research Institute
PWRI: Public Works Research Institute
NIRE: National Institute for Rural Engineering
FFPRI: Forestry and Forest Products Research Institute

OUTLINE OF THE RESEARCH TOPICS

Establishment of utilization and wide area network systems

Fig. 2 shows the schematic illustration of the organization for operation of E-Defense. NIED will establish the Hyogo branch (tentative name) for the operation of the facility and conducting the research work. However, due to shortage in the number of regular staffs, NIED will establish a supporting consortium, as an outsourcing mechanism.

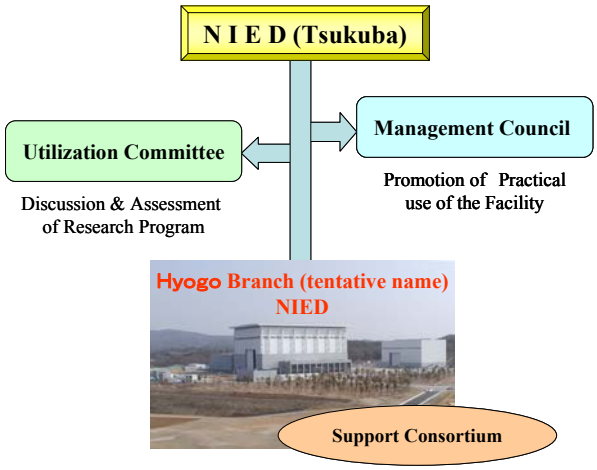

Figure 2 Organizations for Operation of E-Defense

NIED established a council and a committee for more effective management and operation of the facility. The management council is organized by the representatives from government, academic institutions and private sectors. This council will discuss on the medium and the long term management plans and more efficient management of the facility. The utilization committee is organized by active researchers from various fields of earthquake engineering. The committee will discuss on the research plans and results by using this facility.

E-Defense should be operated in a way to facilitate the international common use, as well. Therefore, NIED will construct and install the E-Defense Network (ED-Net). The ED-Net has two major functions. The first one is a connection tool among NIED and other organizations in and outside Japan. The other one is to introduce the information and the experimental results of E-Defense.

Test and analysis of reinforced concrete structures

The purpose of earthquake simulation tests of full-scale reinforced concrete (RC) structures using E-Defense is to investigate a three-dimensional dynamic response and failure mechanism of real structures, and to obtain the data for establishment of 3-D numerical simulation techniques which can evaluate and predict the dynamic behavior of a structure with sufficient accuracy. Further, the results can directly lead to the developments of an advanced method for evaluation of the earthquake-resisting capacity of RC structure, an advanced earthquake-resistant design of a structure and the new structure systems which aim at improvement of seismic performance and the proposal of specific methods for seismic examination and anti-earthquake reinforcement of the existing structures.

This research topic contains the following three general themes for carrying out the above purpose.

1) Experimental study on 3-D earthquake response and earthquake failure mechanisms of structures
2) Development of a 3-D numerical simulation system
3) Decision on an experiment plan using E-defense

As preliminary research on full-scale RC structures leading to collapse using E-Defense, the dynamic shake table tests of RC structure in a 1/3 scale model are being conducted by using the existing 1-D and 3-D shake tables. The results are being studied as the basic data to prepare the full-scale RC structure test plans using E-Defense and to accumulate experiment technology. The data are also being used for studies on dynamic behaviour and failure mechanisms of RC structures. Photo 2 shows a shake table test for RC wall-frame structure which was conducted in March, 2003 in NIED.

Photo 2 Preliminary shake table test for RC wall-frame structure – March 2003

Fig. 3 shows the plan for the model shake table test to be used in E-Defense. The designed RC frame consists of 2x3 spans and the space between the columns in both directions will be 5m. The frame will also consist of six floors and the total height of the structure will reach to 18 m. The total mass of the model structure shown in Fig. 3 will reach to about 800 ton.

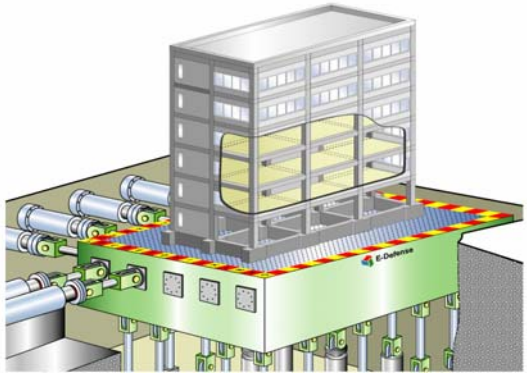

Figure 3 Overall plan of the full-scale RC structure to be used in E-Defense

Test and analysis of soil-pile-structure systems

The purpose of earthquake simulation tests of soil-pile-structure system using an ultra large cylindrical laminar box and a long rigid container in E-Defense is to investigate a three-dimensional dynamic response and failure mechanism of soil-foundation system, and to obtain the data for development of 3-D numerical simulation method which can evaluate and predict the dynamic response of soil-foundation system. Further, the obtained results are contributed to evaluation and improvement of the existing earthquake-resistant design, and development of new technologies and new methods for improving the seismic performance of soil-foundation systems.

This research topic contains the following three general themes for carrying out the above purpose.

1) Experimental studies on dynamic behaviour and failure mechanisms of soil-foundation system
2) Development of the 3-D numerical simulation method for earthquake failure mechanisms of soil-foundation system
3) The experiment plan using E-Defense and fabrication of the experimental devices

Nearly a dozen of research groups are closely collaborating to cover all the preliminary research preparations by a single dead line which is April 2005. There is huge number of tasks going on parallel to each other to minimize the required time.

Fig. 4 illustrates an overall image of the first soil-pile-structure interaction shake table test using an ultra large cylindrical laminar box on E-Defense. In this test, the behaviour of the liquefied sand as well as the pile supported structure on the consequences of the extensive liquefaction will be examined by means of a full scale model.

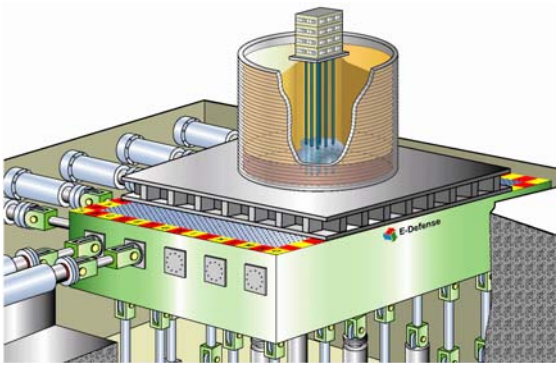

Figure 4 Overall image of the first shaking test plan

Fig. 5 shows the schematic illustration of the shake table with the new long rigid container with quay wall sheet pile, group pile foundation and super-structure which are planed to extensive lateral deformation of the liquefied soil. In this test, the behavior of the liquefied sand as well as the foundation system due to lateral spread of the liquefied sand will be examined by means of a full scale model.

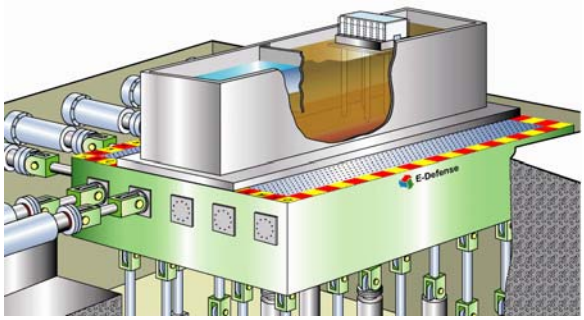

Figure 5 Overall image of the second shaking test plan

Test and analysis of conventional wooden structures

The earthquake simulation tests of full-scale wooden structures using E-Defense have two major purposes. The one is to investigate a three-dimensional dynamic behaviour and evaluation of the earthquake-resisting capacity of the existing conventional wooden structures during major earthquakes, such as Kobe Earthquake, January 17, 1995. The other one is to develop an advanced earthquake-resistance design and anti-earthquake reinforcement of conventional wooden structures.

This research topic contains the following four general themes for carrying out the above purpose.

1) Experimental studies on dynamic and static behaviour and failure mechanisms of the existing conventional wooden structures
2) Seismic observation of the existing conventional wooden structures
3) Development of a 3-D numerical simulation system
4) Decision on an experiment plan using E-Defense

As preliminary research, 3-D middle-scale shake table tests are being conducted on three models; i.e., the wall element unit extracted from an existing conventional wooden structure, full-scale frame model designed by the standard used before the revision of earthquake-resistant standard in 1981, and a wooden frame model with tradition method. These test results serve as the basic data for the full-scale shake table test plans on E-Defense and establishment of the numerical simulation system for dynamic behaviour and failure mechanisms of conventional wooden structures. A preliminary shake table test on 3-D is shown in Photo 3.

Photo 3 Preliminary 3-D shake table test on full-scale wooden frame

There are few seismic observations of the existing conventional wooden structures. Currently, we started seismic observation at two locations in Kanto and Kansai areas in Japan. The difference of earthquake response between observations and the experiment results will be used as the data for evaluation of full-scale tests on E-Defense. Photo 4 shows a conventional wooden house and an installed observation seismograph.

Photo 4 Wooden house and installed observation seismograph

Development of advanced control system for E-Defense

All the efforts in this part of the research are focused on "developing a simulation system for the 3-D shake table". This system will enhance the safety and high accuracy of the shake table tests by E-Defense. The simulation system will mainly be used for the test plan and in pre-analysis it can simulate the table wave with high accuracy. The system is composed of the table model, mechanical system which consists of servo-valves, actuators and 3-D link joints, application-control system, basic-control system and the specimen model which is set on the table. The system will also simulate the effects of the interaction response caused by the mounted model. This system will also provide the possibility of linking to other controlling systems which are being developed in SFC (Special Coordination Funds for Promoting Science and Technology, MEXT) and also to original algorithm of other users of the table. Fig. 6 shows schematic view of the simulation system.

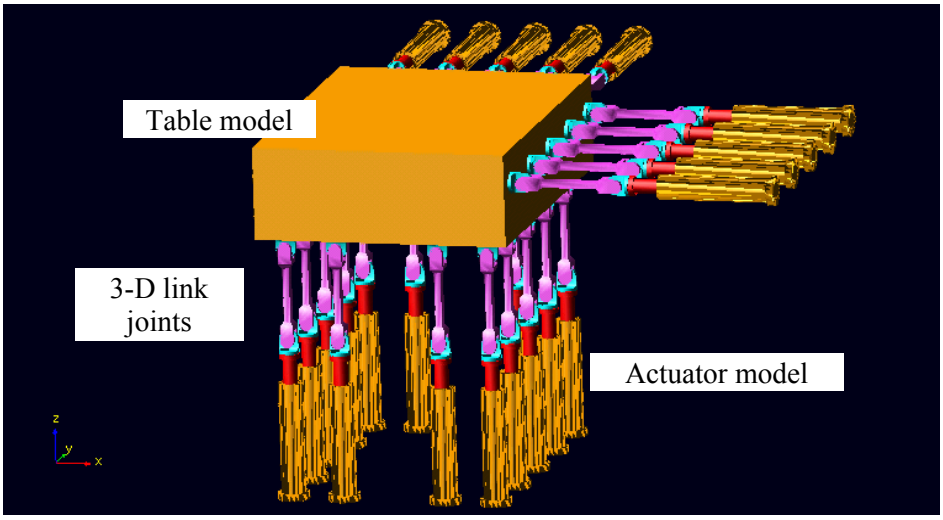

Figure 6 Simulation model

Development of 3-D ground motion database

The purpose of the 3-D ground motion database is to provide input earthquake motion for E-Defense. This database is composed of strong ground motion records and calculated waveforms. The database

is used for data selection search and strong ground motion prediction. Fig. 7 shows search results in a prototype database.

The strong ground motion recorded in and outside Japan is collected for this database and the attributes of the earthquakes, such as hypocenter, magnitude etc., are arranged. Moreover, the technique for 3-D strong ground motion prediction is built, and we can predict 3-D waveforms of a specific site in urban areas by these techniques.

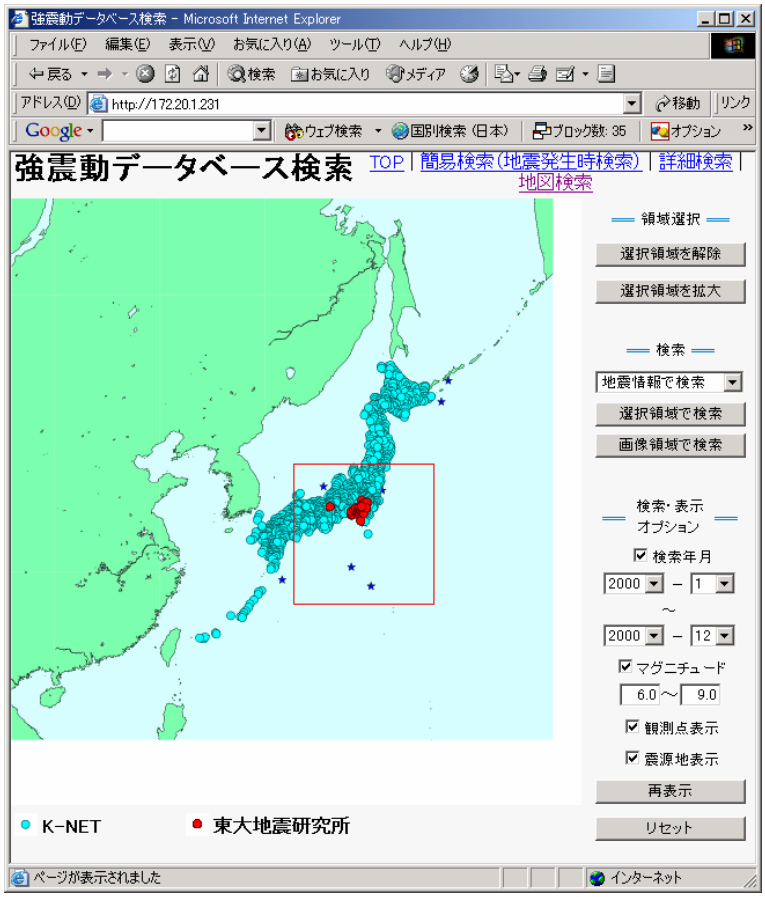

Fig. 7 Search results in a prototype database

CONCLUSIONS

The general framework of the research topics related to E-Defense research project, which is presented in this paper, is an on-going research topic and any may subject to change in some parts. Authors encourage the readers to visit our home pages. The report of this project in first year (2003) is already in print. The research and development are progressing towards establishment of a technical base to mitigate the earthquake disasters, remarkably.

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