EARTHQUAKE ENGINEERING RESEARCH FACILITIES IN NIED: POSSIBLE CONTRIBUTIONS TO INTERNATIONAL DISASTER MITIGATION

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Introduction

There are a large number of cultural structures in countries with high seismic activity along Silk Road. Some of those buildings are world heritages, national/local symbols and/or tourist attractions supporting local economy. It is quite important to preserve them from earthquake events, and high cost-performance seismic retrofit with minimum damages in their historical and cultural specifications needs to be developed. In addition, it should not be forgotten to protect craftsmen inheriting traditional technology for cultural architecture from disasters. For development of optimum disaster mitigation, a series of shake table tests with large- or full-scale specimens is one of the most effective approaches. In fact, researchers and public officers in charge of disaster mitigation in some countries visiting NIED have earnest desire to build this kind of large facilities. However, maintenance of such large-scale facilities requires gigantic cost and high technology. Therefore, it is one of the most reasonable options to obtain basic results from numerical analyses, static tests, and dynamic tests using a small-scale shake table available, and then, develop reasonable research plan and use existing international facility for large-scale experiment. In light of this, it seems valuable to provide fundamental information of two large-scale shake table facilities for common use in NIED as possible international facilities in this paper.

E-Defense Shake Table

The world largest 3-Dimensional Full-Scale Earthquake Testing Facility (Fig. 1), nicknamed "E-Defense" was constructed in the city of Miki, the north-west neighbor of Kobe city by NIED. The most important motivation of building this giant facility was the 1995 Hyogoken Nanbu (Kobe) Earthquake. Because of this background, capacities of E-Defense at the beginning of its operation were designed in order to input earthquake motions observed in Kobe Earthquake to full- or large-scale test specimens (e.g., [1], [2]). Dimensions of this table is 20 m by 15 m, payload is 12 MN and the maximum velocities in horizontal and vertical directions are 2.0 m/s and 0.7 m/s under the maximum loading condition.

In 2011, another tragic earthquake, the 2011 off the Pacific coast of Tohoku (Tohoku) Earthquake happened. Special features of this earthquake were long-duration and -period motions and a main shock followed by large aftershocks at quite short interval as well as tsunami occurrence. Since 2011 Tohoku earthquake, dynamic behaviors and damage accumulation of structures in such earthquakes have become ones of the most noticeable research topics in earthquake engineering because long-duration and -period motions are expected also in future Tokai-Tonankai earthquakes. However, the original E-Defense was

not able to produce these motions with their full intensity because of capacity shortage of its hydraulic system. Therefore, E-Defense had been upgraded in 2013 in order to enable inputting motions recorded in Tohoku earthquake.

As of March, 2016, 80 test projects including some collaborative researches with foreign research organizations have been completed since E-Defense opening. Most of them are related to seismic performance of buildings. Results from those projects provide useful data to capture phenomenon, develop reasonable retrofit and update design guideline. In addition, indoor safety and behaviors of non-structural elements during earthquakes have been evaluated by placing furniture, office facilities, pipelines and ceiling in test structures. More detailed specifications of E-Defense shake table and test movies taken in most of past experiments are available in E-Defense webpage [3].

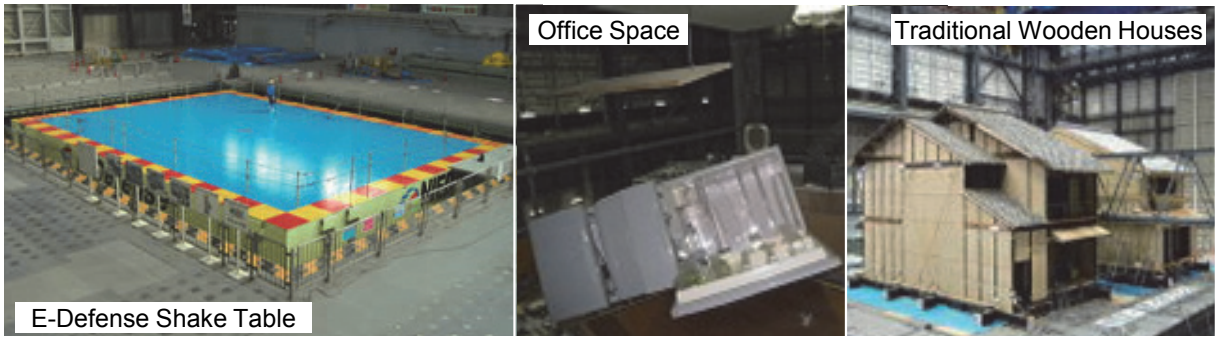

Fig. 1: E-Defense Shake Table and examples of past experiments [3]

Large-scale Earthquake Simulator

The other large shake table, Large-scale Earthquake Simulator (Fig. 2), was established in Tsukuba City by NIED in 1970, and has been used for shake table tests on various kinds of full- or large-scale structures. Results from those experiments have provided great contributions toward improving seismic performance of structures. Through several significant maintenances and upgrades of the facility, it can now produce many of earthquake motions recorded in past events more precisely and shows potential for more sophisticated researches. This shake table can input horizontal 1-directional motion to test specimens placed on. Its dimensions is 15 m by 14.5 m, payload is 5 MN and the maximum velocity is 0.75 m/s under the maximum loading condition Comparing with capacities of E-Defense, ones of Large-scale Earthquake Simulator has considerably less, but it is still sufficient in many cases when the critical direction of motion for structures in interest is obvious. For instance, if experiments with various conditions are necessary, usage of Large-scale Earthquake Simulator is probably more reasonable because of its relatively low cost.

Some examples of test specimens used in past Earthquake Simulator tests are shown in Fig. 2. This shake table is also a facility for common use and various types of research projects have been performed, such as NIED own experiments, domestic and international collaborative researches. As a recent international collaboration, a series of shake table tests on non-engineered masonry houses were performed in 2014 with Indonesian researchers. In this test series, two houses with and without reinforcement were placed on the table, and effectiveness of the reinforcement used could be verified. More information on the shake table and examples of past experiments are available in a webpage of the facility [4] and elsewhere [5].

Fig. 2: Large-scale Earthquake Simulator and examples of past experiments [4]

Research Planning

Performing a series large- or full-scale shake table tests takes significantly large amount of cost, and therefore, it is difficult to do so many times and effective research planning is significantly important. In this section, typical concepts of E-Defense research planning is provided because it may help people who want to have such large facilities in their own countries to get more understanding.

Fig. 3(a) shows a position of E-Defense shake table test to classify its roles in earthquake engineering. It is noticeable that this figure includes only shake table test and analysis, but there are more kinds of research, such as element tests and static load tests. Summary of past research works and performance of fundamental experiments and numerical analyses under various conditions give valuable information to develop reasonable research plan for large-scale experiments. A single large-scale test provides a large number of useful data only under a single test condition, and therefore, the results need to be extended to under other conditions by complementing with the above researches. So, a series of large-scale shake table tests is a big event but occupies a small part of entire research project.

Fig. 3(b) presents a position of E-Defense test included in earthquake engineering in disaster mitigation. In previous times, main objectives of most researches were to capture dynamic behaviors, evaluate seismic performance of structures and update design standards because there were many unknowns. Though there are still many significant unknowns in earthquake engineering, it is not easy to find sufficient budget to perform large-scale experiments only with the above objectives. Therefore, connections between earthquake engineering and others need to be considered as main- or sub-objectives. For instance, a large number of digital cameras are placed in test specimens of recent experiments to take movies for educations on earthquake preparation as well as for engineering purposes. These movies are used to help public obtaining better understanding on earthquake engineering and promote them considering what they can do in emergency.

Possible Contribution to International Disaster Mitigation

E-Defense has accepted a large number of visitors to the shake table. For instance, in the 2014 fiscal year, more than 6,000 people including public officers and engineers from foreign countries had usual or technical tours of the E-Defense facility. Most of the technical tours for foreigners are arranged as international training programs by JICA, other national research institute or universities in Japan. In the tour, more detailed information on the facility and past experiments, such as project planning and testing, are usually provided. For the tour,

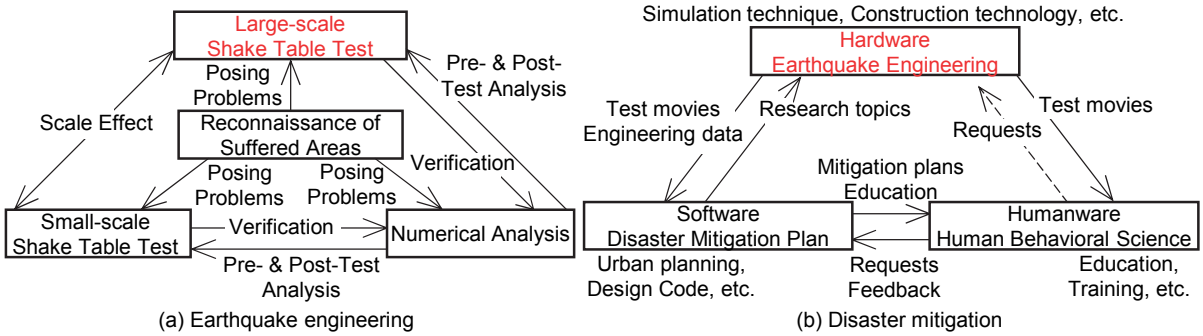

Fig. 3: Positions of E-Defense shake table test

application is required in the webpage [3]. Also, all of E-Defense shake table experiments except private tests are open for public at their test dates. Schedule of the open experiments are published in E-Defense webpage [3] usually only in Japanese approximately one month before the tests.

Research collaboration is another possible option. If specific large-scale shake table projects are under planning, NIED “may” help the projects by performing collaborative experiments or renting the shake table facilities; that is, E-Defense and Earthquake Simulator. In addition, NIED “may” accept engineering trainees learning sequence of large-scale shake table experiments.

Concluding Remarks

In this paper, fundamental information on NIED shake table test facilities is provided. Shake table test is merely one of the indispensable elements in total plans for mitigating disasters from earthquakes, and it is important to develop reasonable total research plan including facility management by considering other kinds of experiments and numerical analyses. Also, various factors, such as politics, economy and culture, need to be taken into account for effective mitigation. Performing effective researches for disaster mitigation, significant contribution to preservation of cultural architecture can be made. At the last moment in this paper, contributions from all researchers and engineers are gratefully acknowledged.

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