MISSIONS AND PARTICULAR ACTIVITIES OF THE CENTER FOR ADVANCED ENGINEERING STRUCTURAL ASSESSMENT AND RESEARCH (CAESAR)

Atsushi YOSHIOKA[1]

Abstract

With recent rapid increase in demand for structural condition assessment and rehabilitation of existing highway bridges the Center for Advanced Engineering Structural Assessment and Research, CAESAR, was established in April 2008, as one of four Research Institutes and Centers of the Public Works Research Institute, Tsukuba, Japan. This paper presents a review of the background, mission, organization, and research areas of the new organization, CAESAR, in addition to their expected impacts on highway bridge administration practices.

Introduction

Public Works Research Institute, which is one of the Japanese incorporated administrative agencies, established the Center for Advanced Engineering Structural Assessment and Research (CAESAR) as of April 1st, 2008, recognizing increased social needs for appropriate maintenance of existing structures. As a core research center in Japan, it accumulates findings related to maintenance technology of the structures. This paper describes the background of establishment of CAESAR, organization and system, mission, and new activities.

Background

The majority of highway bridges in Japan were constructed during the 1950s–1970s, which coincides with Japan's high-growth period. Accordingly, bridges older than 50 years will increase drastically in the coming years. Moreover, highway bridges in Japan are exposed to severe automobile traffic and natural environment; it is highly probable that the deterioration and damage will increase rapidly. Consequently, under tight financial circumstances, technologies related to inspection, assessment, diagnosis, repair, and reinforcement should be established urgently for the sake of preventive maintenance.

Figure 1 portrays a comparison of the transitions of the numbers of highway bridges by year of construction for Japan and the U.S. As a whole, bridges in Japan are about 30 years younger than those in the U.S. However, many instances of damage such as fatigue of

[1] Acting director of CAESAR, Center for Advanced Engineering Structural Assessment and Research, Public Works Research Institute, Tsukuba, Japan

floor slabs, fatigue of steel girders and beams, and salt corrosion and alkali-silica reaction of concrete members have already been recognized as the national major defects, which strongly influence bridge load-bearing characteristics. For example, such trouble was reported two years ago that a fatigue crack exceeding 1 m in length developed in a main girder of a steel girder bridge around a part welded to a cross beam (Yamazoe Bridge, National Route 25). Last year, a tension diagonal bracing of a steel truss bridge (Kiso River Greater Bridge, National Route 23, Honjyo Ohashi, National Route 7) fractured because of corrosion or some similar cause. In all these cases, traffic restrictions were enforced temporarily for repair, resulting in a considerable social impact. Regarding overseas trouble, the I-35W Bridge (Minneapolis, Minnesota, U.S.) collapsed in August 2007 despite the fact that detailed inspections, actual bridge measurements, and status assessments had been carried out annually.

In Japan, infrastructure was heavily damaged by the Hyogo-ken Nanbu (Kobe) Earthquake in 1995. In recent years, large-scale earthquakes have occurred successively: the Niigata Chuetsu Earthquake in 2004, the Noto Peninsula Earthquake and Niigata Chuetsu-Oki Earthquake in 2007, in addition to the Iwate-Miyagi Inland Earthquake, which occurred this year. Improvement of disaster prevention and mitigation technologies has been requested to cope with the increasing sophistication of socioeconomic activities.

Recognizing the increased social needs described above, the Public Works Research Institute established the “Center for Advanced Engineering Structural Assessment and Research (hereinafter designated as CAESAR)” as of April 1st, 2008 by reorganizing existing research organizations for additional progression. This is a comprehensive research organization examining issues related to highway bridges including bridge design and construction technology, maintenance and management technology, long-life technology, and disaster mitigation.

Organization and system

As shown in Figure 2, CAESAR is one of four research organizations constituting the Public Works Research Institute. The research teams of bridge engineering, foundation engineering, management, and earthquake engineering were restructured, with staff at the establishment of CAESAR of 26. In addition, four researchers from the Tsukuba Central Research Institute and Civil Engineering Research Institute for Cold Region are also on call so that construction material and severe cold environment effect can be also covered.

CAESAR tackles every research need in a flexible fashion, covering a wider range of the bridge engineering field. It does not employ a conventional research organization system of PWRI to create organizations and systems. While the PWRI’s former highway bridge-related research teams were organized in terms of major highway bridge components and materials (such as metal superstructures, concrete superstructures, substructures, and seismic design), CAESAR adopted a radically different approach, -- one where interdisciplinary communication and support are stressed. The rehabilitation and seismic reinforcement of older bridges involve a much more multifaceted and complicated series of issues than those encountered during conventional design/construction efforts. For older bridges, a comprehensive structural assessment of the entire structure is often required. For example, when designing a seismic reinforcement of an existing steel bridge, the structure's overall state of deterioration and the possible negative side effects of the planned reinforcement method on the fatigue vulnerability must be taken into account. Therefore, in CAESAR, now researchers are assigned on a project-by-project basis to ensure interdisciplinary collaboration across all disciplines.

As shown in Figure 3, respective specialists of superstructure, substructure, earthquake engineering, fundamental materials, and cold region construction technology promote research and technical development. This group also is intended to be an organization with abundant comprehensive strength for design and construction, disaster mitigation, inspection, diagnosis and prognosis, rehabilitation and reinforcement, and management systems. Areas of the superstructure to substructure of the bridge are considered as a total system.

Research coordinator for earthquake engineering in Figure 2 is responsible for organizing individual research projects related to earthquake engineering including bridges and other road and river structures covered by all PWRI's research institutes and centers. When a large-scale earthquake occurs, the coordinator urgently summons researchers from CAESAR, Tsukuba Central Research Institute, and Civil Engineering Research Institute for Cold Region to send an emergency survey team. When required by the regional development bureau and local public authorities after the earthquake, the coordinator also directs technical assistance activities.

Roles and activities

CAESAR provides technical supports to highway administrators and conducts research with a much closer relationship with them, as shown in Figures 4 and 5. CAESAR especially covers highly sophisticated issues for which relevant diagnosis and prognosis technique, assessment method, or corrective method has not been generally understood. While highway administrators need information to judge how serious that damage is, how soon it should be treated, and what remedial method should be chosen or what, CAESAR provides technical assistance using cutting-edge technology even though it is in the middle of development. For example, Figure 8 shows an example of an on-site test of the on-going project of a fatigue prevention technique for steel deck plates utilizing SFRC (steel fiber reinforced concrete) pavement. In addition, CAESAR continues follow-up activities after an assessment was conducted or a corrective measure was taken. While CAESAR accumulates findings from the site, it develops and improves cutting-edge technology to resolve such an issue. That's what CAESAR calls scientific trials. CAESAR pursues this kind of win-win cycle between highway administrators and the CAESAR's research activities.

CAESAR also intends to be the meeting ground of highway administrators, academic sector, and private sector to shear and exchange state-of-the-art information and yield collaborations.

Then CAESAR's know-how based on the findings obtained through the scientific trial and meeting ground are presented by technical guidelines and reports as well as a knowledge database for engineers that will be developed. CAESAR also continues to contribute to developing national technical standards as the Tsukuba Research Institute done before. It is crucial that experiences and findings obtained through scientific trials be fed back successively to the design and construction of new bridges and be fed back to the rehabilitation of existing bridges to make bridges easier to maintain and have a longer service life.

Research and development based on scientific trials

While CAESAR also conducts basic research as was done before, a scientific trial approach is the new key activity in CAESAR as described above. Structural conditions, construction status (initial construction quality, etc.), and environmental and traffic conditions are different bridge by bridge. Therefore, CAESAR assigns greater importance to a scientific trial approach to resolve technical issues for maintaining individual bridges. For example, in cooperation of highway administrators and other technology developers, several bridges are chosen throughout Japan, and then many kinds of nondestructive test and behavior measurement technique are tested to assess the damage status in practice even inside the cross-section. One other example is the follow-up inspection of the effectiveness of earlier corrective measures in actual bridges and the deterioration of the materials used in earlier rehabilitations.

When any damage is noticed for a certain member or portion of the bridge, the urgency, priority, and required level of corrective action depends on how much that damage can affect the bridge system structural performance. Because each bridge has the uncertainty of structural conditions, it is difficult to assess the precise degree of structural soundness. Specifically, long-term reliable information related to structural durability is rarely available. It is therefore necessary to accumulate findings bridging a continuous monitoring and nondestructive measurement result on the development and progress of deterioration of material to the load-bearing characteristic of the structure. As shown in Figure 7, scientific trials and anatomical surveys are under progress using bridges and structural members that will be removed, so that the influence of any damage or deterioration of a member or material upon the soundness of the whole bridge system should be assessed more appropriately.

Earthquake engineering is another key technology in CAESAR, and the scientific trial approach is also adopted. For example, CAESAR supports highway administrators when they reinforced older bridges against strong earthquakes, and the bridges that were reinforced based on a PWRI research result had no serious damage (Photos 2 and 3) in recent strong earthquakes. Now CAESAR keeps improving post-earthquake strengthening methods for RC piers, testing very rapid repair work methods that are simple, easy, and fast, and which utilize materials that are easy to obtain, such as carbon-fiber sheet and polyester bands (Photo 4)

Verification measure

CAESAR will address standardization of rehabilitation technologies. The point is that it will also include a verification measure to confirm whether a proposed repair or a rehabilitation/reinforcement technique meets the performance requirements under given various conditions and clarify the limitation of application. For example, the PWRI's standard tests for the fatigue durability of deck plates and the seismic ductility for piers have been gaining wide acceptance (Photo 5).

CAESAR takes over the mission to develop the Japanese Specifications for Highway Bridges and other design directions and guidance that were originally undertaken by the Tsukuba Central Research Institute, because it is very important that findings obtained through corrective actions and disaster mitigations have to be fed back sequentially to the design and construction of new bridges. For example, problems are often related to the initial construction and design qualities. CAESAR has been preparing for the next revision of the Japanese Specifications for Highway Bridges, which will be based on a performance-based specification concept, involving a reliability design concept.

Remarks

Previous bridge-related research teams in Tsukuba Central Research Institute and Civil Engineering Research Institute for Cold Region were restructured to enhance their achievement and work interdisciplinary and Center for Advanced Engineering Structural Assessment and Research was established in April 2008. CAESAR is organized especially to be able to respond precisely and timely to needs of society and highway administrators in a flexible manner beyond the framework of the existing studies. Therefore, the scientific trail approach is considered to be crucial while basic research also runs.

The acronym CAESAR was inspired by Julius Caesar of the Roman Empire, who established and maintained the infrastructure of long empire-wide highway network -- parts of which are still in use more than 2000 years later. We hope our new CAESAR research center will forge ahead with an equally strong will, and thus ensure we can complete our missions. Collaborative work with related research organizations will be highly appreciated.

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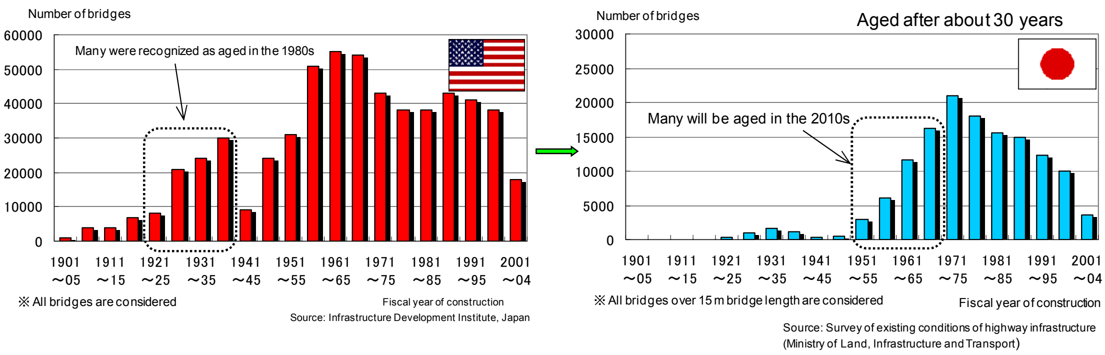

Figure 1 Transition of the number of highway bridges by fiscal year of construction in Japan and the U.S.

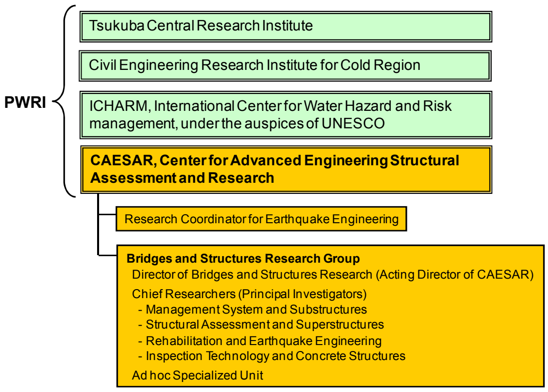

Figure 2 Organization chart of CAESAR (CAESAR) and Public Works Research Institute

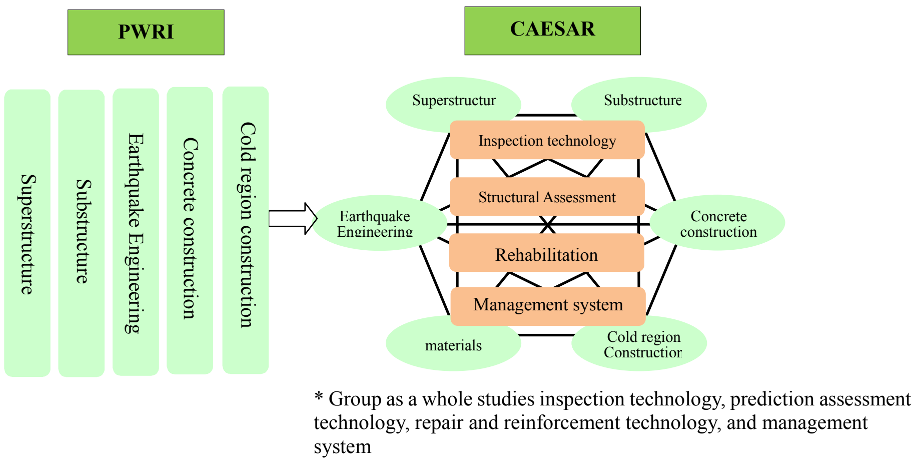

Figure 3 Difference between conventional organization and CAESAR related to bridges in the Public Works Research Institute

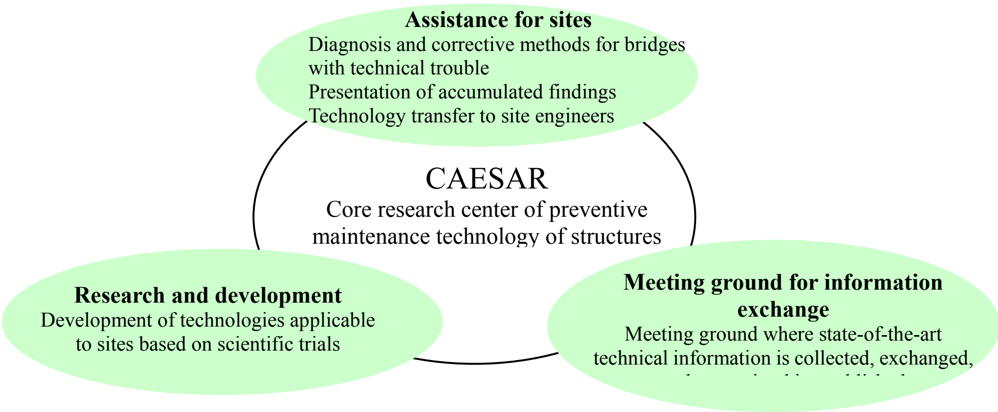

Figure 4 Mission

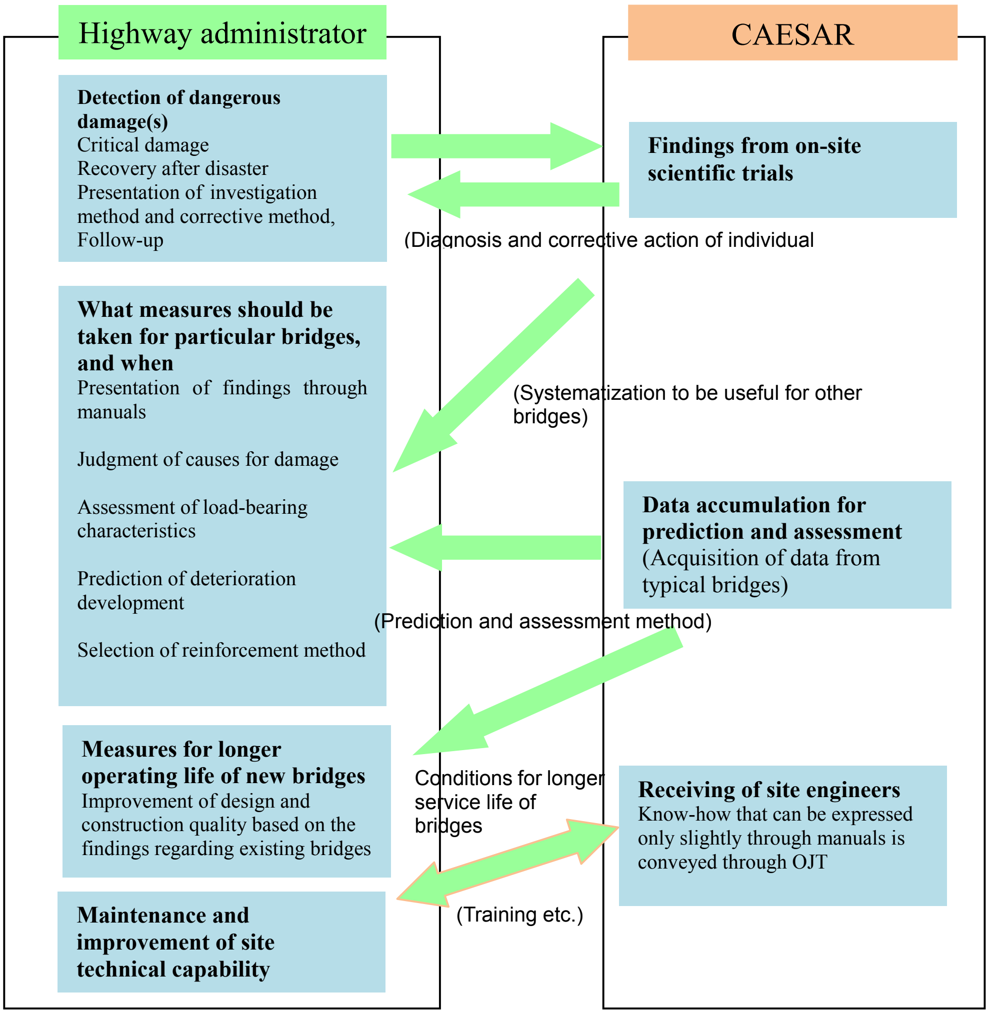

Figure 5 Scientific trials: a cycle of a technical assistance for highway administrators and the corresponding research activities of CAESAR

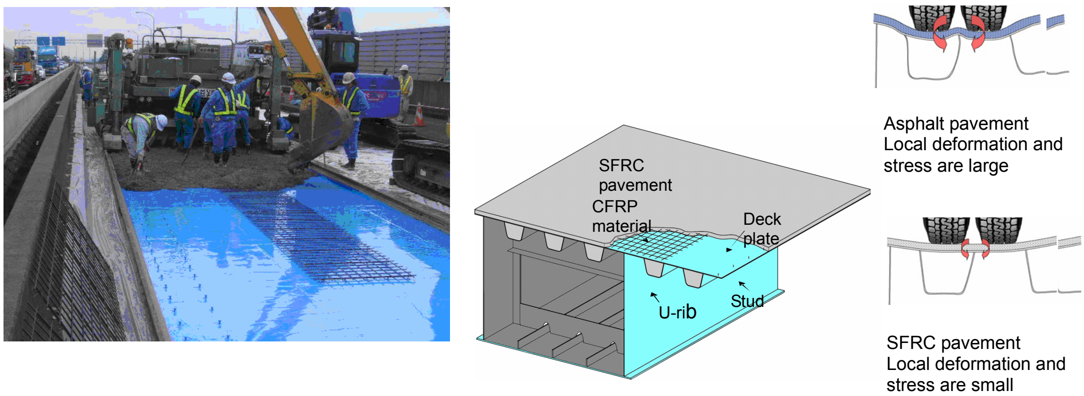

Figure 6 Fatigue durability improvement technology of existing steel floor slab using steel fiber reinforcement concrete (SFRC)

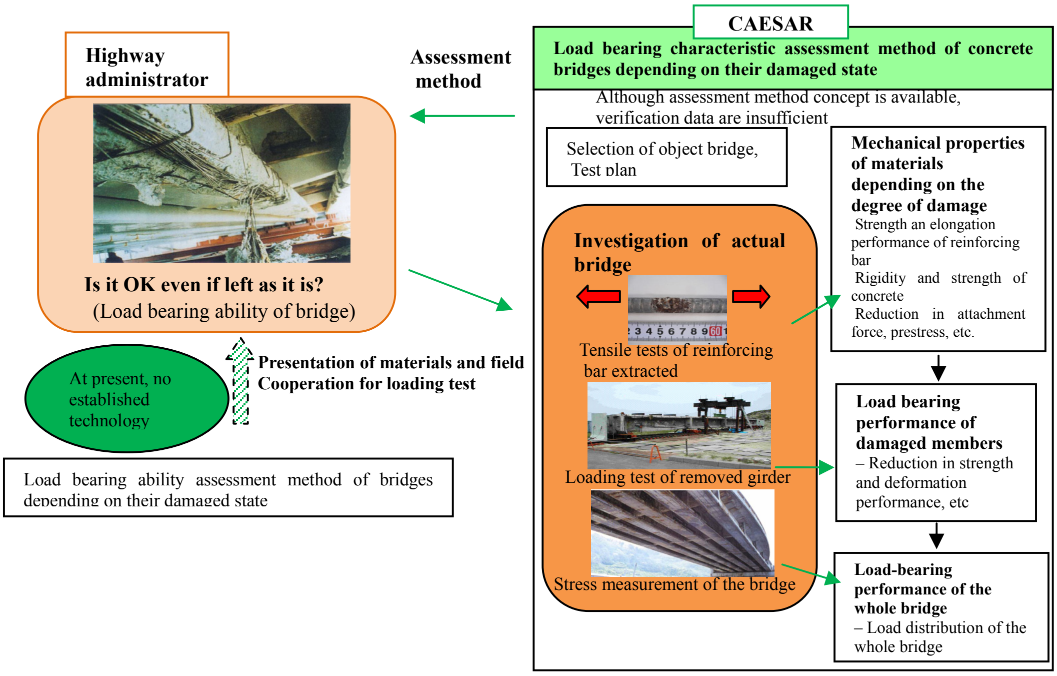

Figure 7 Image of scientific trials related to load-bearing characteristic assessment technologies for damaged bridges

Photo 1 Nondestructive inspection techniques to detect hidden problems. (A) Field test of a UT (ultrasonic scanning) method to detect defects in metal deck plates, and (B) Test of a self-potential method to detect corrosion of reinforcement bars inside concrete.

Photo 2 Undamaged and damaged piers next to each other following the 2004 Niigata Chuetsu earthquake (Mj6.8), in which undamaged piers were reinforced as part of a seismic reinforcement program

Photo 3 A long span bridge that did not suffer damage during the 2007 Niigata-ken Chuestu-oki earthquake (Mj6.8) because of seismic reinforcement provided by the PWRI.

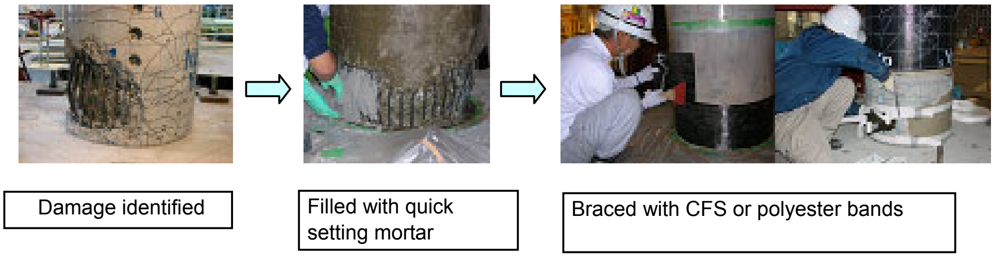

Photo 4 Easy-to-apply emergency recovery technology for RC bridge columns after an earthquake

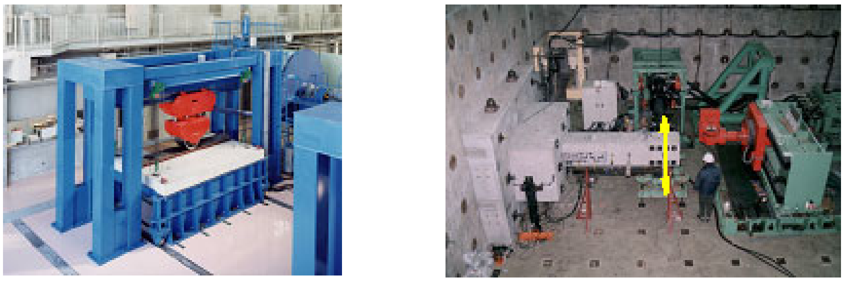

Photo 5 Tests for deck plate fatigue durability (left) and bridge pier ductility (right)