RESEARCH ACTIVITY UTILIZING DECOMMISSIONED CONCRETE BRIDGES IN CAESAR

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Abstract

One of the pillars of research activities of Center for Advanced Engineering Structural Assessment and Research (CAESAR) is a “clinical study.” And the research utilizing decommissioned bridges is a component of it. The final goal of the study is to establish evaluation methods for deteriorated bridges. In this paper, recent cases of concrete bridge deficiencies and CAESAR’s activity utilizing decommissioned concrete bridges are presented.

Introduction

As the nation’s core research agency, CAESAR was established in April, 2008 in Public Works Research Institute (PWRI). This is a comprehensive research organization examining issues related to highway bridges including bridge design and construction technology, maintenance and management technology, technology to prolong service life, and disaster mitigation to stay ahead of the problems caused by such decay.

One of the pillars of its research activity is a “clinical study” which is an analogy from the medical research field. Similar to the medical counterpart, it requires accumulation of cases of deceases (deficiencies), cases of autopsies of dead bodies (decommissioned bridges), studies of tissues (bridge components), and studies of treatments (repair or rehabilitation works). As a component of the clinical study, CAESAR is tackling the study utilizing decommissioned bridges.

Recent Cases of Concrete Bridge Deficiencies

As one of the tusks, CAESAR is consulted by bridge operators, such as Regional Development Bureaus (RDBs) of the Ministry of Land, Infrastructure, Transport and Tourism (MLIT) or municipalities, regarding their bridges with deficiencies. In this section, some recent cases of deficiencies of concrete bridges reported in these consultations are shown.

Chloride-induced deterioration is a major issue in the maintenance of concrete bridges. Although the sea salt prone area is limited to small parts of Japan, deterioration is very severe since it will reduce the sectional area of steel members inside of concrete which play important role in terms of strength of bridges. Photo 1 shows a recent collapse of a

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concrete bridge in Okinawa, which is the southernmost part and one of the most severe sea salt environment in Japan. The bridge had been closed to traffic at the time of collapse since most of the rebars were lost because of the corrosion. Photo 2 is a bridge severely damaged by chloride-induced deterioration. In the large portion of the girders, cover concrete fell off because of the expansion pressure by corroded reinforcing bars. The bridge will be demolished in a short while.

Photo 1 Collapsed Concrete Bridge in Okinawa

Photo 2 Concrete Bridge with Cover Concrete Fell Off

Deterioration caused by alkali silica reaction (ASR) became major problems since 1980's. Through many studies about this phenomenon, it was found that structural strength may not degrade very much despite its stunning appearance, such as wide cracks on the surface of the concrete. However, in some cases of ASR, breakages of rebars because of the expanding pressure of concrete were found. This may have a significant effect against structural integrity. Photo 3 shows a horizontal crack found on the side of the precast hollow girder. Similar cracks were found on the side of the other girders of the bridge. Especially they concentrate at the end of girders. For the prestressed structures suffering ASR, it is known that longitudinal cracks along prestressing direction may appear. Also, ASR may be accelerated when water is supplied. The end of girder is a portion where wrongly drained water from road surface may supply a lot of moisture. From these observations, this bridge is considered to suffer ASR. Photo 4 is a PC hollow bridge with similar cracks.

The number of cases with insufficient grouting in prestressed concrete bridges is increasing nowadays. For those bridges, water including sea salt or deicing salt may seep into sheathes and cause corrosion of PC cables. While signs of deterioration, such as cracks or leakage of rusty water, may appear on the surface of the concrete in typical chloride-induced deterioration, no signs may appear in this type of deterioration since corroded metal, such as sheathes or PC cables, can freely expand inside of void sheathes and may not damage surrounding concrete. Photo 5 shows a corroded PC cables in a precast segment box girder bridge. Through investigation, it was found that grout was not properly filled in the most of the sheathes. Many cables were already broken. It is noteworthy that rebars adjacent to PC cables are almost intact condition. Photo 6 shows a similar damage found on the webs of a T-shape girder bridge. Also some PC cables were found broken in this bridge.

Precast PC girders were considered to have reliable quality since they are manufactured inside factories where level of quality control is much higher than in-situ manufacturing sites. Photo 7 shows a recent defect found in a bridge with precast hollow girders. A large void was found in the bottom flange of the girder. The size of the void was 100cm long and 30cm wide. The void was created by faulty workmanship at the time of manufacturing. After finding this problem, the operator surveyed bridges with same type girders constructed at the same period and found some more bridges with similar defects.

Photo 3 Horizontal Crack on Precast Hollow Girder

Photo 4 Diagonal Crack at the End of PC Hollow Bridge Girder

Photo 5 Corroded and Broken PC Cables in Precast Segment Box Girder Bridge

Photo 6 Corroded PC Cables in T-Shape Girder Bridge

Photo 7 Void in Bottom Flange of Precast Hollow Girder

Goal of Research Activity

For the operators of the deficient bridges such as the ones listed above, the most important issue is how to judge serviceability, i.e., continuing service, restriction of vehicle weight, immediate traffic closure, or demolition. In the design stage of bridges, materials considered are, of course, intact state. Cracks, corroded rebars, or voids are not considered. However, what they have to evaluate is the remaining strength of the bridges with such deteriorated materials or components. Furthermore, condition inside the concrete is usually hard to grasp even with state-of-the-art non-destructive testing devices. For this evaluation, special consideration must be made.

The goal of the research is to establish evaluation methods for deteriorated concrete bridges. In order to achieve this goal, the following three issues are focused in the study utilizing decommissioned concrete bridges.

1. Relation between the visible defects on the surface of the concrete members and corrosion level of internal steel members

   Since the current inspection method according to the Inspection Manual issued by MLIT is visual inspection, it is desirable to grasp the condition of internal steel members, which play important role for the strength of the concrete member, from the external defects appeared on the surface of the concrete members. If the relation between them is obtained to some extent, it is very useful to evaluate the condition of the concrete member.

2. Remaining strength of deteriorated members

   Even though the condition of the internal steel members can be obtained, some unknown factors still remain, which may affect the residual strength of the concrete bridge, such as bond between steel members and concrete, functionality of separated concrete cover, and so forth. These unknowns must be evaluated by many samples of loading test results with deteriorated bridge members.

3. Development of non-destructive testing (NDT) methods

   Since the visible inspection has limitation to assess the condition of the bridge members, development of NDT methods is expected. CAESAR is planning to offer decommissioned bridge members to the developers of NDT devices in order to evaluate their performance.

Partners for Research Activity

Through RDBs, CAESAR is collecting information of bridges, which are planned to be demolished, operated by RDBs and municipalities since 2009. From the list of such bridges, CAESAR makes shortlist by their deterioration level, types of structure, years built, and so forth. Directors for Road Management in RDBs and their staff support CAESAR’s research activity.

In May 2010, CAESAR and Japan Prestressed Concrete Contractors Association (JPCCA) signed a cooperation agreement regarding a study utilizing decommissioned PC bridges. JPCCA is a collective entity of contractors constructing PC bridges. Construction technique of concrete bridges went through various transitions and, therefore, is an important factor affecting the performance of concrete bridges. JPCCA has accumulated variable information regarding construction, such as concrete casting method, assemblage of formworks, arrangement of rebars, grouting method, and so forth, through longtime construction experience. Through the cooperation with JPCCA, it is expected to identify the period when vulnerable PC bridges were constructed.

Facilities for Study

CAESAR already owns testing facilities for its research, such as 30 MN large-scale universal testing machine, wheel-load test run machine, and so forth. CAESAR also constructed a stock yard of 1,700 m^2 for members of decommissioned bridges (Photo 8) in 2009. The yard is used not only as a stock yard of members until they are tested but also as a display ground for visitors.

Photo 8 CAESAR’s Stock Yard for Decommissioned Bridges

Current Activity

Grouting condition was investigated when a PC bridge was demolished. The bridge was constructed in 1972 and served for 38 years. Because of the chloride-induced deterioration, the operator decided to replace the bridge. T-shaped girders were cut at slab and removed one by one. Then each girder was split into 6 parts. From each section, grouting condition was examined. For this bridge, grout was filled properly in most of the section. However, at a section where one cable is anchored at upper flange, void was found in the sheath (Section2, Figure 1).

The anchor at the upper flange was common method before 1990s when the large-scale anchor methods are not popular. This anchor method is not desirable since the water seepage from the road surface may intrude into the anchor and causes corrosion. The method gradually disappeared as new anchoring method, which can anchor all the cables at the end of the girders, became popular. Figure 2 shows a transition of anchoring method for standard T-shaped post tension PC girder issued by the Ministry. Also, unlike today’s non-bleeding grout material, bleeding was allowed to a certain level for grout material at the time of the construction. Bleeding tends to concentrate at higher level and consequently it creates void there. In this kind of anchor method with old grout material, void tends to be created at the anchor part.

CAESAR will continue this survey for more PC bridges to collect more samples.

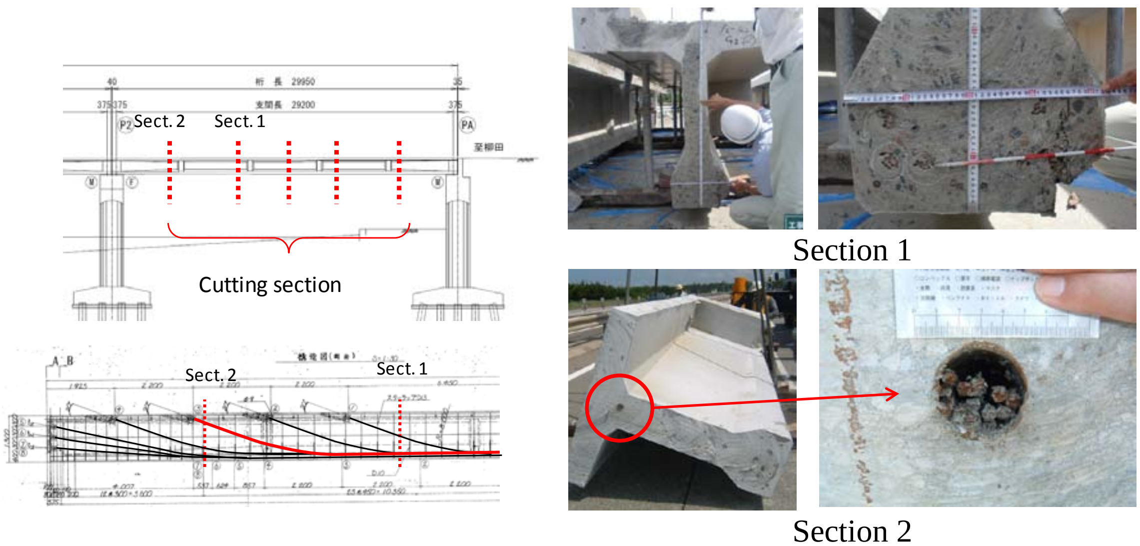

Figure 1 Grout Condition of T-Shaped PC Bridge

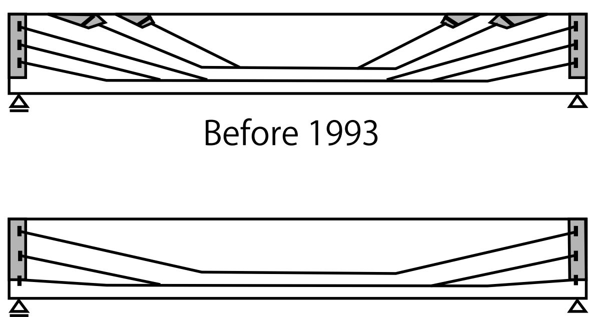

Figure 2 Transition of PC Cable Anchoring Method for Standard T-Shaped Post Tension PC Girder

In order to evaluate the remaining strength of bridges with chloride-induced deterioration, several loading tests using decommissioned bridges are now being prepared. Photo 9 is a RC slab deck bridge with heavily corroded rebars. The bridge was already removed and transferred to CAESAR's stock yard. Photo 10 is a RC T-shaped girder bridge. The bridge went through multiple repair works, such as concrete coating, attachment of reinforcing plates under the lower flanges, and so forth. But finally, the operator decided to replace the bridge since the chloride contents already intruded inside concrete caused further deterioration even after the coating. Two girders will be transferred to CAESAR for loading test. For both bridges, chloride contents will be measured to obtain the relation between chloride concentration and corrosion level of rebars.

In order to obtain the relation between the visible external condition of concrete members and internal steel condition, CAESAR is planning to sample some concrete bridges. Photo 11 shows a RC bridge that served about 80 years and will be demolished soon. Close visual inspection was conducted and precise defect map including width and length of cracks was made. Condition of steel members under the cracks will be investigated in CAESAR's laboratory. In spite of its long service, the surface condition was relatively fair.

Photo 9 RC Slab Bridge Before Demolition

Photo 10 RC T-Shaped Girder Bridge with Multiple Repair Works

Photo 11 RC T-Shaped Girder Bridge Served about 80 Years

Concluding Remarks

Compared with steel structures, uncertain factors tend to increase in the process of construction of concrete structures since the proportion of in-situ operation is much higher than that of steel. Also, since the steel members are embedded in concrete, these components are usually invisible and their condition is hard to be assessed. From these points of views, maintenance of concrete structures requires comprehensive knowledge.

The research utilizing decommissioned bridges is a methodology to enhance reliable maintenance strategy. CAESAR will continue the research activity.

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