April 7, 2011

JSCE Concrete Committee
Subcommittee for Survey of Great East Japan Earthquake
Damage and Countermeasures
Survey Team on Damage to Concrete Structures in
Fukushima Prefecture

JSCE Structural Engineering Committee
Great East Japan Earthquake Damage Survey Team

Report on Damage to (Civil Engineering) Concrete Structures in Fukushima Prefecture (First Report)

1. Outline of survey

1.1 Introduction

A survey of the damage caused by the Great East Japan Earthquake to railway viaducts (on the Tohoku Shinkansen line) and road viaducts (on national, prefectural, and city administered roads) in the Nakadori area of Fukushima Prefecture was conducted by a joint JSCE survey team. The joint team (known as the Joint Survey Team of the JSCE Concrete and Structural Engineering Committees) consists of the Survey Team on Damage to Concrete Structures in Fukushima Prefecture (part of the Subcommittee for Survey of Great East Japan Earthquake Damage and Countermeasures under the JSCE Concrete Committee) and the Great East Japan Earthquake Damage Survey Team (under the JSCE Structural Engineering Committee). This report summarizes the results of the survey. In consideration of the current situation in the disaster-stricken region and the government's advice to evacuate or stay indoors in certain areas to avoid radiation, structures in the tsunami-hit Pacific coast region of Hamadori in Fukushima Prefecture were not surveyed.

The Great East Japan Earthquake occurred around 14:46 on Friday March 11, 2011. Its seismic intensity, as issued by the Japan Meteorological Agency, was Upper 6 on the Japanese intensity scale of Upper 6 in Kagamishi Town, Upper 6 to Lower 6 in Sukagawa City, Lower 6 in Koriyama City, and Upper 5 to Lower 5 in Fukushima City. That is, the highest seismic intensity measured in Fukushima Prefecture was Upper 6.

The survey was carried out under the on-site guidance of responsible persons from East Japan Railway Company, the Ministry of Land, Infrastructure, Transport and Tourism, Fukushima Prefecture office, and Fukushima City office. The survey team visited various sites by car over a period of two days: March 29 (Tuesday) and March 30 (Wednesday), 2011. In Koriyama City, the team's base, the gasoline supply status had improved immediately before the survey and there was no problem obtaining gasoline for the survey.

During the survey, the major damage observed was to bridge piers, rigid-frame viaduct columns, and girder ends. No structures had completely collapsed. Damage other than to these major structural members was seen in displacement control mechanisms, expansion joints, curbs, and bridge railings. The cause of the damage to these members was longitudinal or transverse motion of girders caused by the earthquake. Damaged Tohoku Shinkansen line viaducts had already undergone emergency repair work or were being repaired at the time of this survey.

1.2 Survey team members

Team leader: Ichiro IWAKI (Nihon University)

Team members: Takumi SHIMOMURA (Nagaoka University of Technology), Minoru KUNIEDA (Nagoya University), Kenichiro NAKARAI (Gunma University), Kouhei NAGAI (Tokyo University), and Satoshi TAKAYA (Kyoto University)

Observer: Yasuhiro KODA (Nihon University)

1.3 Survey route

March 29, 2011 (Tuesday)

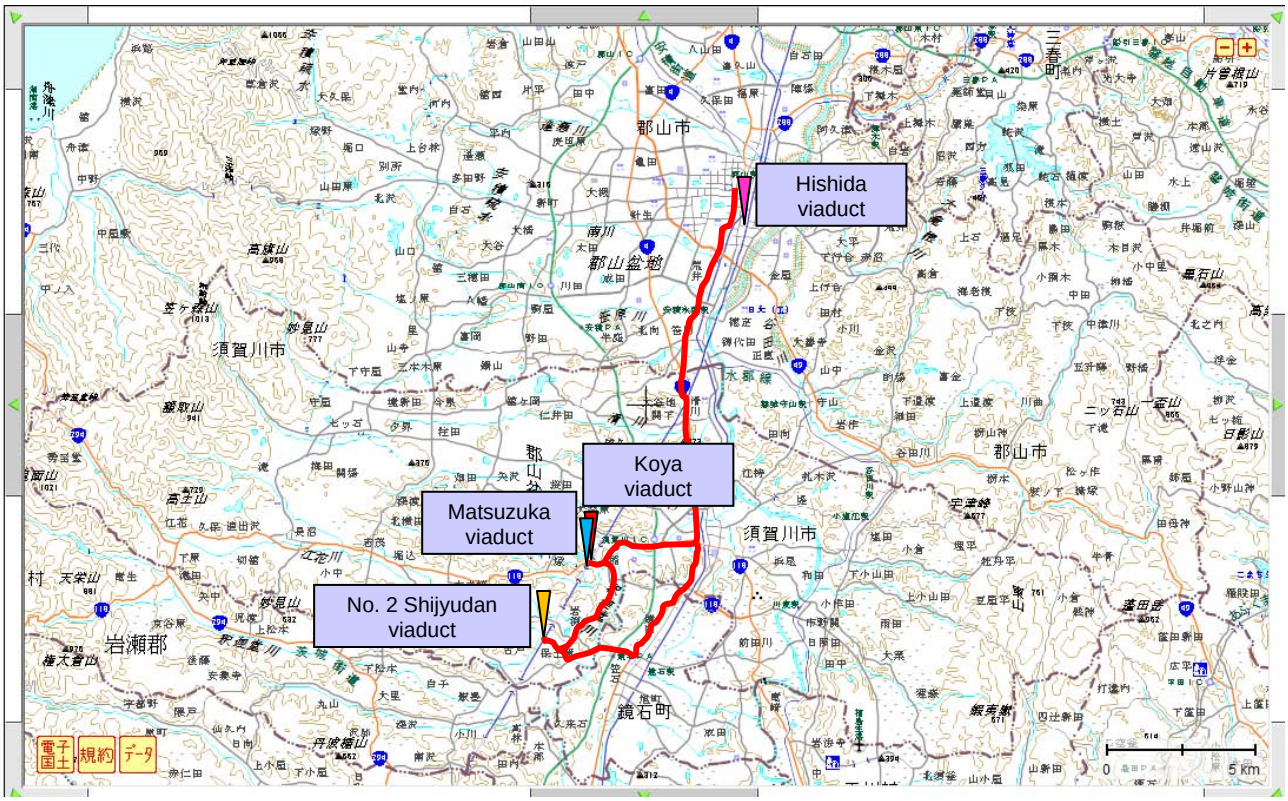
13:10 Depart from West Exit of Koriyama Station → 13:25 Hishida viaduct → 14:20 Koya viaduct → 14:45 Matsuzuka viaduct → 15:20 No. 2 Shijyudan viaduct → 16:20 College of Engineering, Nihon University (meeting) → 18:00 Arrive at Koriyama View Hotel

March 30, 2011(Wednesday)

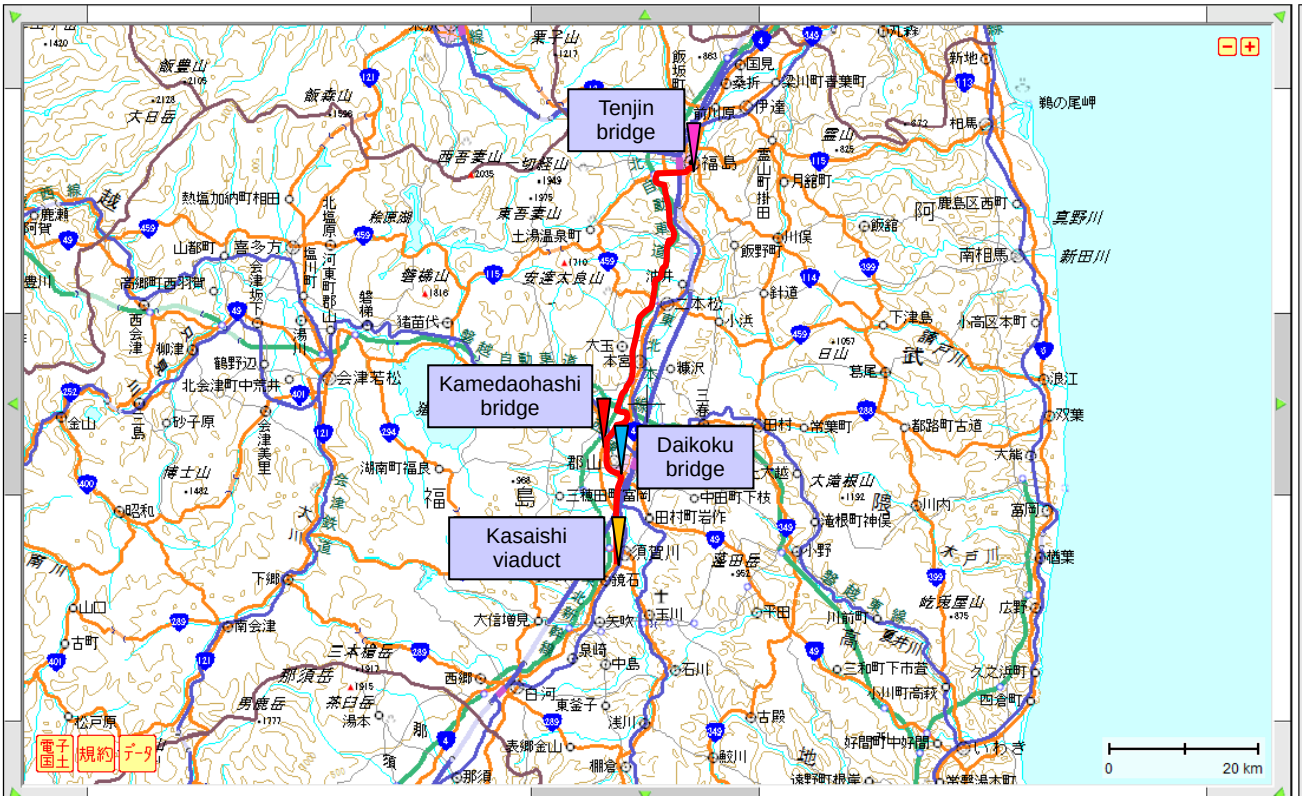
8:30 Depart Koriyama View Hotel Annex → 9:20 Kasaishi viaduct → 10:50 Daikoku bridge → 12:10 Kamedaohashi bridge → 14:15 Tenjin bridge → 16:20 Arrive at Koriyama View Hotel Annex

1.4 Location of structures surveyed

The locations of structures surveyed and survey routes are indicated on the following maps.



Location of structures (railway bridges) surveyed on the first day (March 29)
(Source: Cyber Japan, URL http://cyberjapan.jp/)



Location of structures (road bridges) surveyed on the second day (March 30)
(Source: Cyber Japan, URL http://cyberjapan.jp/)

2. Survey results (railway bridges)

2.1 Hishida Viaduct

Date of survey: March 29, 2011 (Tuesday), 13:25-13:50

Structure surveyed: Hishida Viaduct (P15)

Type of structure: Girder type viaduct

Location: Within Koriyama General Passenger Carriage Center, Hishida Town, Koriyama City, Fukushima Prefecture (between Shin Shirakawa and Koriyama Stations)

Administrator of structure: East Japan Railway Company

Date of completion: July 1978

Damaged member: RC single-column type bridge pier

Outline of survey results:

The structure surveyed was a girder type viaduct on the Tohoku Shinkansen line. The damaged pier supports two PC girders, one with a 40 m span and the other with a 30 m span. Concrete in a region about 50 cm in width had broken away, mainly near the rebar cut-off plane where the cross-sectional area of the pier changes. Emergency repair work had already been completed at the time of the survey. This consisted of arranging tie hoops in the damaged portion and pouring in non-shrinkage mortar. Similar damage was observed to a second bridge pier (P13) some distance away.

	
Hishida Viaduct P15 Damage near the rebar cut-off plane where the cross-sectional area changes (Under repair, Source: East Japan Railway Company)	Hishida Viaduct P15 After repair (at the time of the survey)

2.2 Koya Viaduct

Date of survey: March 29, 2011 (Tuesday), 14:20-14:40

Structure surveyed: Koya Viaduct

Type of structure: Girder type viaduct

Location: Matsuzuka, Sukagawa City, Fukushima Prefecture (between Shin Shirakawa and Koriyama Stations on the Tohoku Shinkansen line)

Administrator of structure: East Japan Railway Company

Date of completion: July 1976

Damaged member: RC stopper for girder fall prevention

Outline of survey results:

The structure surveyed was a girder type viaduct on the Tohoku Shinkansen line. The bridge pier of wall-type construction had already undergone seismic retrofit and a RC stopper designed to prevent the girder falling from the pier was added after the Off-Miyagi-Prefecture Earthquake. The stopper was damaged by the seismic forces of the Great East Japan Earthquake. Around the survey point, earthquake damage was more severe than in nearby areas: roof tiles had fallen and road shoulders had collapsed. The area seemed to have been hit by strong local shaking. Cracks in the ground were observed at the base of the viaduct pier, as shown in the lower photo.

To repair the lightly-damaged RC stopper, which is shown in the upper left photo, a repair material was being injected into the cracks. For the damaged steel shoe, which functions to restrict movement of the girder, H-section steel was being fixed in place to restore functionality, as shown in the upper right photo.

Koya Viaduct
Damage to RC stopper designed to prevent falling of the girder

Koya Viaduct
Repairs to steel restrictor shoe

Koya Viaduct
Cracks in ground at base of viaduct pier

2.3 Matsuzuka Viaduct

Date of survey: March 29, 2011 (Tuesday), 14:45-15:10

Structure surveyed: Matsuzuka Viaduct

Type of structure: Girder type viaduct

Location: Matsuzuka, Sukagawa City, Fukushima Prefecture (between Shin Shirakawa and Koriyama Stations on the Tohoku Shinkansen line)

Administrator of structure: East Japan Railway Company

Date of completion: May 1978 (August 1978 in part)

Damaged member: RC stopper for girder fall prevention

Outline of survey results:

Damage was observed to a RC stopper placed between the twin girders as well as to girder supports on the outside edges of the pier. Transverse girder movement resulting from earthquake motion had caused the damage. The girders themselves were undamaged. No noticeable damage was found in the seismically retrofitted columns, either above or below the ground.

At the time of the survey, both the girder supports and the RC stopper were being repaired. Temporary H-section steel stoppers had been fitted.

Matsuzuka Viaduct
Damaged girder support

Matsuzuka Viaduct
Damaged girder support (close-up)

Matsuzuka Viaduct
Damaged RC stopper designed to prevent falling of the girder

2.4 No. 2 Shijyudan Viaduct

Date of survey: March 29, 2011 (Tuesday), 15:20-15:45

Structure surveyed: No. 2 Shijyudan Viaduct

Type of structure: RC rigid frame viaduct

Location: Hodowara, Sukagawa City, Fukushima Prefecture (between Shin Shirakawa and Koriyama Stations on the Tohoku Shinkansen line

Administrator of structure: East Japan Railway Company

Date of completion: January 1979

Damaged members: Columns

Outline of survey results:

Cover concrete had spalled off from the tops of columns supporting the rigid frame viaduct. The degree of damage varied by columns, with the end columns supporting simple girders suffering relatively greater damage than intermediate columns. Repair work was in progress at the time of the survey. Columns that had suffered relatively major damage were being repaired by restoring their original cross-sectional area, while those that had suffered minor damage were being repaired by grouting the cracks with resin.

No. 2 Shijyudan Viaduct
Damaged columns being repaired by restoration of their full cross-sectional area

No. 2 Shijyudan Viaduct
Damaged columns being repaired by grouting the cracks with resin

3. Survey results (road bridges)

3.1 Kasaishi Viaduct

Date of survey: Mar. 30 (Wed.) 2011, 9:20-10:20

Structure surveyed: Kasaishi Viaduct

Type of structure: Girder type viaduct

Location: Kagamiishi Town, Iwase County, Fukushima Prefecture (on Prefectural Road No. 288 known as the Narita-Kagamida route)

Administrator of structure: Fukushima Prefecture

Date of completion: 1991-1993

Damaged members: Expansion joints, displacement control mechanisms, and others

Outline of survey results:

The structure surveyed was a girder type viaduct on Fukushima Prefectural Road No. 288. Where the viaduct crosses the JR Tohoku railway line, there is a pre-tensioned simple PC T-section girder with a span of 23 m, while the side span sections are continuous hollow slab girders with spans 3 x 26 m and 5

x 18.5 m. The foundations for the RC bridge piers consist of steel piles (ø800 mm, 28 m long, and 4-6 piles per pier).

At the survey point, the earthquake motion measured Upper 6 on the Japanese intensity scale of 0 to 7, and damage such as to roof tiles in the area was more prominent than at other survey points in Fukushima Prefecture.

Under the strong earthquake motion, the bridge piers suffered minor flexural cracking damage, the girders underwent a relative displacement of 5 cm in the longitudinal (Southwest) direction, and the girder ends were damaged. However, the major structural members escaped major damage.

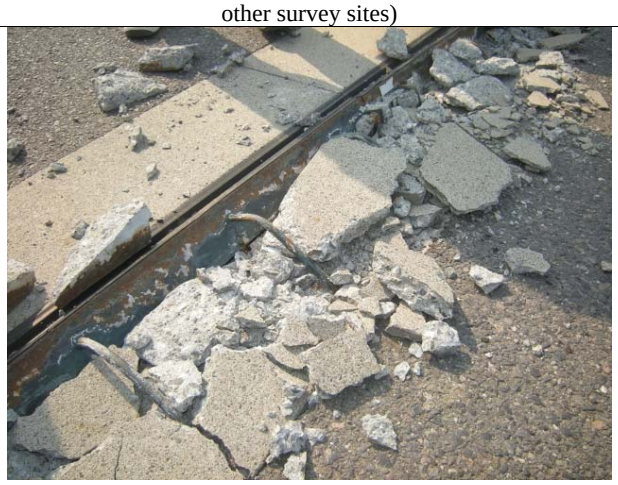
Expansion joints and bridge abutment parapets were severely damaged. RC stoppers designed to restrict the movement of girders in the transverse direction were damaged, along with anchor bars. Strong earthquake motion induced longitudinal (Northwest-Southeast) displacement of the girders, causing them to collide with each other or with the viaduct abutments. In addition, there was other observed damage: post-earthquake consolidation settlement of fill at the rear of the viaduct abutments; breakage of lighting posts; and damage to curbs and bridge railings.

The viaduct had been closed to vehicular traffic and drivers were using detours at the time of the survey.

Kasaishi Viaduct
P2 onward
There was no noticeable damage to major structural members.

Conditions around Kasaishi Viaduct
(Photo taken from on the viaduct)
Damaged roof tiles of private residences (more prominent than in other survey sites)

Kasaishi Viaduct
Above A1
Damaged parapet (left), expansion joint, curb, and bridge railing



Kasaishi Viaduct
Above P4
Damaged expansion joint (steel bars forced upward by compressive force generated during girder collision)

	
Kasaishi Viaduct Above P4 Horizontal residual displacement of girders (about 5 cm) and damaged expansion joint	Kasaishi Viaduct A2 Damaged displacement control mechanism (anchor bar damage and fallen concrete base

3.2 Daikoku Bridge

Date of survey: March 30, 2011 (Wednesday), 10:50-11:40

Structure surveyed: Daikoku Bridge

Type of structure:

A1-P2 – simple post-tensioned PC girder bridge

P2-P3 – simple Warren truss girder through bridge in steel

P3-A2 – simple post-tensioned PC girder bridge

Location: Asaka, Koriyama City, Fukushima Prefecture

Administrator of structure: Koriyama City (transferred from Fukushima Prefecture)

Date of completion: 1966

Damaged members: Bearings, girder seats, lighting posts

Outline of survey results:

The Daikoku Bridge was constructed in 1966 and carries a road over the JR Tohoku railway line. At the bridge abutment joint, a difference in roadway level of 40-50 mm in level near was observed. This was caused by subsidence of earthworks. Concrete had spalled off from the girder seat and bearing side block. Truss member rivets had been severed. The glass enclosure of a light fixture had fallen off. There were undulations in the sidewalk near the bridge abutment. Bearings and truss joints had been deformed. No major damage, such as cracking, was observed in the concrete of the main structural components.

Daikoku Bridge
General view
Combines post-tensioned PC girder spans at both ends with a simple truss girder bridge in the center. Abutment A1 visible at far end in the photo

Daikokubashi Bridge
Roadway at joint between A1 and P1
Level difference of 40-50 mm due to the subsidence of earthworks. Cracks observed on bridge deck face

Daikokubashi Bridge
G1
Peeling paint at truss joints and displacement of truss members

Daikokubashi Bridge
P4 girder support
Spalled off concrete at girder seat and bearing side block

Daikokubashi Bridge
Joint between P2 and G2
Severed rivets

Daikokubashi Bridge
Sidewalk
Undulations in sidewalk. These undulations were symmetric in the sidewalks on both sides. The damage was probably due to subsidence of earthworks, but the cause has not been proven

3.3 Kamedaohashi Bridge

Date of survey: March 30, 2011 (Wednesday), 12:10-12:50

Structure surveyed: Kamedaohashi Bridge

Type of structure: Girder type viaduct

Location: Shimo Kameda, Koriyama City, Fukushima Prefecture (National Road No. 4, section known as Asakano Bypass)

Administrator of structure: Tohoku Regional Bureau, Ministry of Land, Infrastructure, Transport and Tourism

Date of completion:

P5 on down side: opened to traffic in 1990 (erection of superstructure completed in 1987); seismic retrofit by RC jacketing in 2005; RC stopper constructed in 2010

P5 on up side: opened to traffic in 2001 (erection of superstructure completed in 1997); seismic retrofit by addition of RC stoppers in 2010

Damaged members: Bridge piers P5 (on up and down sides)

Outline of survey results:

The structure surveyed is a girder type viaduct on the National Road No. 4 bypass. The surveyed section is a two-span continuous steel box girder bridge (where the entire Kamedaohashi bridge consists of eight spans). The length of this surveyed section is 119 m (where the total bridge length is 280 m). The foundations of RC bridge piers are cast-in-situ piles. The bearings on the up side, which was completed in 1990, are of steel while on the down side, completed in 2001, they are rubber. The bridge piers on the down side had already undergone seismic retrofit by RC jacketing. National Road No. 49 runs under the bridge.

The March 11 earthquake measured Lower 6 on the Japanese seismic intensity scale of 0 to 7 at a site about 2 km away from the survey point.

Under earthquake forces, vertical cracks up to 11 mm in maximum width developed from the top of the beam of Pier P5 on the down side, passing right through the 2.1 m thick main structural body. The residual deformation of the steel bearing was small and the bearing did not come into contact with the added stopper. As regards pier P5 on the up side, the rubber bearing underwent large deformation and the stopper broke, but vertical cracking damage to the main body of the pier was minor.

No noticeable damage was found to structures other than pier P5.

Based on the results of a study of emergency repair work carried out after the March 11 earthquake and an on-site survey conducted by the National Institute for Land and Infrastructure Management and the Public Research Institute on March 16, supports were put in place, the beam of the pier on the down side was reinforced with external cables, and a loading test was conducted. One lane was opened to traffic at 19:10 on March 17. At the time of the survey many vehicles were using the bridge. Permanent repair measures will be studied by the Tohoku Regional Bureau with advice from the National Institute for Land and Infrastructure Management and the Public Research Institute.

Kamedaohashi Bridge
General view
(Center left: P5 on up side; center right: P5 on down side)

Kamedaohashi Bridge
P5 (left: down side; right: up side)

Kamedaohashi Bridge
P5 on down side (steel bearing)
Vertical cracks developed from the end of the steel bearing
(maximum width: 11 mm)

Kamedaohashi Bridge
P5 on down side (stopper)
Undamaged stopper

Kamedaohashi Bridge
P5 on up side (rubber bearing and RC stopper)
Deformed rubber bearing and damaged RC stopper

Kamedaohashi Bridge
P5 on up side (RC stopper)
Damage around stopper block

Kamedaohashi Bridge
P6
No noticeable damage

3.4 Tenjin Bridge

Date of survey: March 30, 2011 (Wednesday), 14:15-15:00

Structure surveyed: Tenjin Bridge

Type of structure: Cantilever box girder bridge

Location: Ogura Town, Fukushima City, Fukushima Prefecture

Administrator of structure: Fukushima City

Date of completion: 1964

Damaged members: Shoes

Outline of survey results:

The Tenjinbashi Bridge crosses the Abukuma river right next to the Fukushima Prefectural Government Office. It is a box girder bridge constructed in 1964 and fitted with a mechanism to prevent falling of the bridge girders in 1995. Under strong earthquake motion, this fall-prevention mechanism operated and tension forces were imposed on the shoes. This caused large cracks to occur in the shoes. A Fukushima prefectural officer stated that the cracks grew larger during every aftershock and had developed considerably since immediately after the main earthquake. Damage was particularly severe at the fixed end A2, with lighter damage observed at the A1 end. Aside from this damage to the shoes, no major damage was observed to the main structural body of the bridge.

Tenjin Bbridge
General view
The Fukushima Prefectural Government Office, where a task force was set up to address earthquake damage, can be seen across the river. The near side in this photo is A1

Tenjin Bbridge
Bridge deck surface
Cracks were observed

Tenjin Bridge
Bridge railings
A few centimeters of clearance is seen at bridge railing joints, which gives evidence of the magnitude of the earthquake motion

Tenjin Bridge
A2
The girder fall-prevention mechanism is attached to the shoe

	
Tenjin Bridge A2 shoe Large cracks (10-20 mm wide) developed in the concrete to which the girder fall-prevention mechanism is fitted. Some of the concrete fell away	Tenjin Bridge A1 shoe Cracks could just be observed through a clearance, although they are not clearly visible. The width of these cracks is unclear. The cracks could be seen using a telescopic sight.