Report on damage to concrete structures in Iwate Prefecture

March 30, 2011 (First Report)

1. Outline of survey

1.1 Introduction

This report gives the results of a survey of damage caused by the Great East Japan Earthquake to concrete structures in the inland areas of Iwate Prefecture, especially viaducts on the Shinkansen line (which suffered relatively severe damage) and structures on the Tohoku Expressway, national and local roads, and local Japan Railways (JR) line. The survey took place over two days (March 25 and 26, 2011). Structures in the tsunami-stricken coastal region on the Pacific Ocean side of Iwate Prefecture, where efforts were continuing to find the missing, were not surveyed. The number of days available for the survey was limited and gasoline shortages were restricting local people's mobility at the time of the survey. In order to gain access without locally refueling the vehicles used by survey members, the range of the survey was limited.

The survey was conducted under the on-site guidance of responsible persons from East Nippon Expressway Co., Ltd. and East Japan Railway Co., Ltd. All viaducts on the Tohoku Shinkansen line between Morioka and Shin Hanamaki Stations, where relatively severe damage occurred, were surveyed in detail on foot. The survey team split into groups to survey the damage over a wide area, with transport mainly in official cars provided by Hirosaki University but also by train in some areas.

The survey revealed that most viaducts on the Tohoku Shinkansen line between Morioka and Ichinoseki Stations suffered minor damage, while damage was concentrated on a few, such as No. 1 Nakasone BL, as described later. These damaged viaducts were not consecutive. All damaged sections had already undergone emergency repair work by the time of the survey. An interview with the responsible person at East Japan Railway Co., Ltd. confirmed that in areas of Iwate Prefecture, which were not covered by the survey, damage was minor and emergency repairs had already been carried out.

Similarly, an interview with the responsible person at East Nippon Expressway Co., Ltd. confirmed that the expressway between Morioka IC and Ichinoseki IC had suffered only minor damage. The survey team conducted an additional survey on three bridges on the expressway and confirmed that the damage was minor. Some of the survey team members left Hirosaki University and traveled from Oowani Hirosaki interchange (IC) in Aomori Prefecture through Akita Prefecture to Morioka IC and found no major damage during the trip.

1.2 Survey members

Tomohiro MIKI (Kobe University)
Akihiko KAMIHARAKO (Hirosaki University)
Yasushi TANAKA (Nagaoka University of Technology)
Yoshinobu OSHIMA (Kyoto University)
Kouji MATSUMOTO (Tokyo Institute of Technology)

1.3 Survey itinerary

Dates: March 24-27, 2011 (actual surveys: March 25 and 26, 2011)

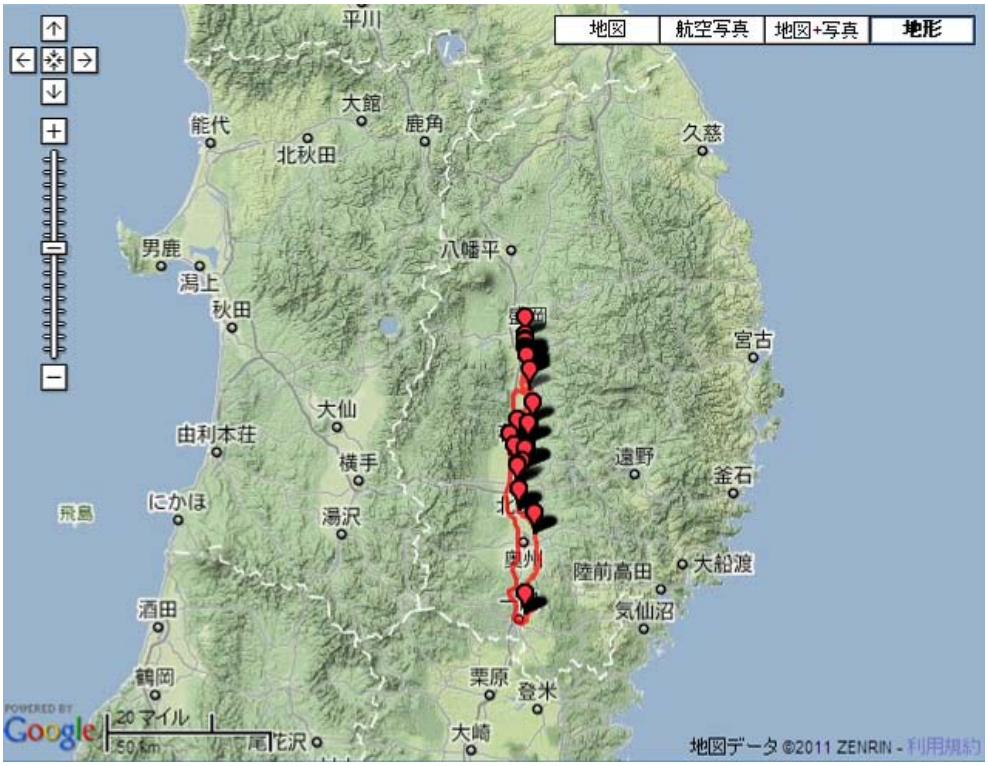
Survey locations:

Tohoku Shinkansen line (between Morioka and Ichinoseki Stations)

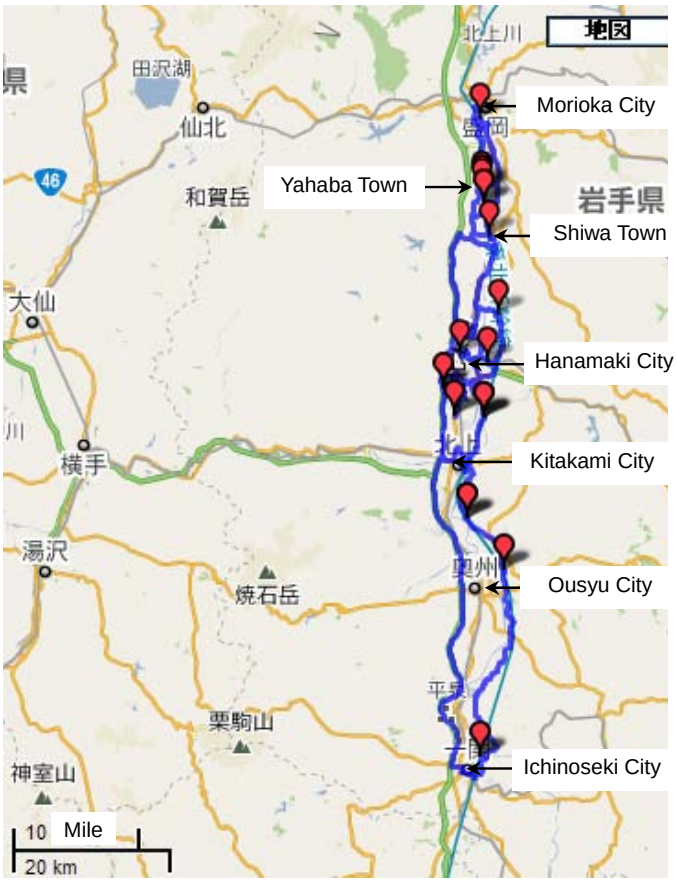
Tohoku Expressway (between Morioka IC and Ichinoseki IC)

Part of JR Tohoku line (between Morioka and Hanamaki Stations)

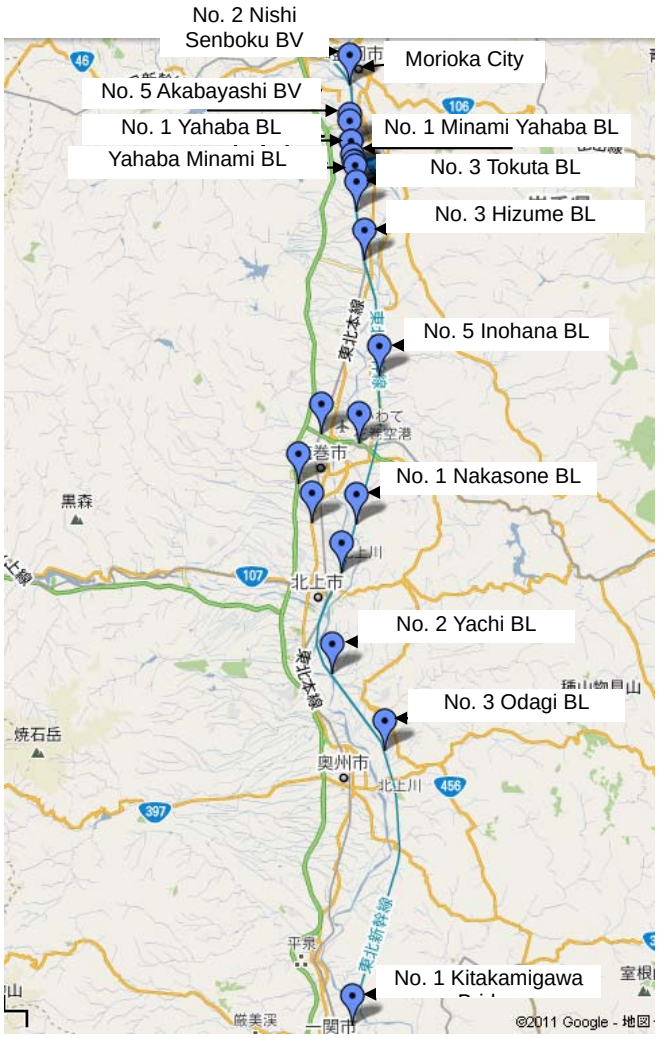
Part of National Road No. 4



Map of survey locations
(Red marks and lines indicate structures surveyed and the survey route, respectively.)
(Map based on Google Maps)



Map indicating survey locations (cities and towns)



Map indicating viaducts on the Shinkansen line

2. Tohoku Shinkansen line (between Morioka and Ichinoseki Stations)

The structures surveyed were classified based on whether they had previously undergone seismic retrofitting or not as follows:

* Not yet seismically retrofitted: structures that had not yet undergone seismic retrofitted (because it had been judged unnecessary)
* Seismically retrofitted: structures that had already undergone seismic retrofitting
* Seismically retrofitted following damage: structures that had been damaged in the 2003 South Sanriku Earthquake and that had subsequently undergone seismic repair by either the RC jacketing or steel jacketing method (not including those with minor repairs by grouting cracks)

1) No. 2 Nishi Senboku BV (Not yet seismically retrofitted) at the 494.803-km mark (measured from Tokyo)

- Undamaged

No. 2 Nishi Senboku BV
Undamaged

No. 2 Nishi Senboku BV
Undamaged

2) No. 1 Akabayashi BL (Not yet seismically retrofitted) around the 488.018-km mark

- R1 and R3: Undamaged
- R2: Columns at both north and south ends of the rigid frame were damaged. (repaired)

No. 1 Akabayashi BL
R3 and subsequent rigid frames: undamaged

No. 1 Akabayashi BL
R1: undamaged
R2 (left column): damaged (and repaired)

No. 1 Akabayashi BL

R1 and preceding rigid frames: undamaged

No. 1 Akabayashi BL

R2 (columns at both ends): damaged (and repaired)

(The nearer rigid frame in the photo is R2.)

Emergency repair work was being carried out on the two columns at the Tokyo end and one column at the Morioka end. No noticeable damage was observed on intermediate columns, although flexural cracking was seen.

No. 1 Akabayashi BL

R2 north end columns: damaged (and repaired)

Of the R2 bridge pier columns at the north, only the right column (on the near side of this photo) was being repaired. R3 on the far side in this photo was undamaged.

3) No. 1 Yahaba BL (Not yet seismically retrofitted) around the 485.937-km mark

- Undamaged

 No. 1 Yahaba BL 4P: undamaged	 No. 1 Yahaba BL 9P: undamaged

4) No. 1 Minami Yahaba BL (Seismically retrofitted) around the 485.533-km mark

- Undamaged

 No. 1 Minami Yahaba BL 12P and subsequent piers: undamaged Bridge piers had already undergone seismic retrofitted by the RC jacketing method. (Thickness of RC jacketing unknown)	 No. 1 Minami Yahaba BL 8P: undamaged The bridge pier had already undergone seismic retrofitting by the RC jacketing method. (Thickness of RC jacket: 20 cm)

5) Yahaba Minami BL (Partly seismically retrofitted) around the 485.135-km mark

- Cracks in the middle-layer beams in the transverse direction.

 Yahaba Minami BL R4 to R11	 Yahaba Minami BL R2 to R4
 Yahaba Minami BL R1 and R2	 Yahaba Minami BL From the right: Ainono BV P1, R11 to R10 No noticeable damage was found in columns, although shear cracking had occurred in the 1st story transverse beams.

 Yahaba Minami BL R11 (4-span 2-story rigid frame: the 2nd-story columns had undergone seismic retrofitting with steel jacketing) The 1st-story transverse beams: fine cracks were found.	 Yahaba Minami BL R11 (closeup of the 1st-story beam end in photo to the left) The 1st-story transverse beams: fine cracks were found.
 Yahaba Minami BL R6 to R10 (2-story rigid frame; not yet seismically retrofitted) The 1st-story transverse beams: cracks were found.	 Yahaba Minami BL R6 to R10 (closeup of the 1st-story beam end in photo to the left) The 1st-story transverse beams: cracks were found.

 Yahaba Minami BL R1 to R5 (2-story rigid frame; the 2-story columns had undergone seismic retrofitting with steel jacketing) The 1st-story transverse beams: fine cracks were found.	 Yahaba Minami BL R1 to R5 (closeup of the 1st-story beam end in photo to the left) The 1st-story transverse beams: fine cracks were found.

6) No. 3 Tokuta BL (Not yet seismically retrofitted) around the 483.713-km mark

- R1 column at the starting point side: Damaged (repaired)

 No. 3 Tokuta BL R1 columns at the South end: damaged (and repaired)	 No. 3 Tokuta BL R1 intermediate column: cracks were observed (not yet repaired) X-shaped diagonal cracks were found on the column surface facing the longitudinal direction

7) No. 3 Hizume BL (Seismically reinforced after damage) around the 479.547-km mark

- Undamaged

	
No. 3 Hizume BL R1 and R2: Undamaged Columns had already undergone seismic retrofitting with steel jacketing.	No. 3 Hizume BL R1 side columns Columns had already undergone seismic retrofitting with steel jacketing.

8) No. 5 Inohana BL (Partly seismically retrofitted after damage) around the 469.291-km mark

- R13 and R14 (Seismically retrofitted after damage): undamaged (but backfill around bridge piers had deformed)
- R12 to R1 (Not yet seismically retrofitted): undamaged (as visually checked from a distance)

	
No. 5 Inohana BL R1 to R12 (Not yet seismically retrofitted)	No. 5 Inohana BL R13 (Seismically retrofitted after damage)

No. 5 Inohana BL

R14 (Seismically retrofitted after damage)

No. 5 Inohana BL

R13 in foreground and R14 behind: no damage to main structural members

Columns had already undergone seismic retrofitting with steel jacketing.

No. 5 Inohana BL

R13: gap between column base and fill

9) No. 1 Nakasone BL (Not yet seismically retrofitted) around the 456.171-km mark

R9 to R4: 3-span a single story rigid frame viaduct, R3 to R1: 4-span a single story rigid frame viaduct

- R1 to R3: four side columns were damaged (and had been repaired).
- R4: concrete cover spalled off from the western side column at the south end; the remaining three sides of the column suffered diagonal cracking.
- R5: four side columns suffered diagonal cracking.
- R6: four side columns were damaged (and had been repaired).
- R7: four side columns were damaged; two intermediate columns at the north end were damaged (and had been repaired).

No. 1 Nakasone BL

R1 North-end columns and R2 South-end columns: damaged

(Repaired by jacking up the columns, replacing rebars, and restoring the reduced cross-sectional area.)

No. 1 Nakasone BL

R1 North-end columns: damaged (and repaired)

The work of restoring the reduced cross-sectional area by repairing the lost cover concrete was being carried out over a large area of the surface. To restore the rebar arrangement, the cross-sectional area was restored over a large area in the axial direction.

No. 1 Nakasone BL

R2 North-end columns: damaged (and repaired)

The work of restoring the reduced cross-sectional area by repairing the lost cover concrete was being carried out over a large surface area. To restore the rebar arrangement, the cross-sectional area was restored over a large surface area in the axial direction.

No. 1 Nakasone BL

R3 South-end column: damaged (and repaired)

The sectional size of the column was unchanged after work to restore the cross-sectional area was completed.

No. 1 Nakasone BL

R3 North-end columns: damaged (and repaired)

R4 end-column at South-end: diagonal cracking was observed.

No. 1 Nakasone BL

R7 North-end columns: damaged (and repaired)

Tilted catenary poles

10) No. 2 Yachi BL (Partly seismically retrofitted) at the 441.934-km mark

3-span 2-story rigid frame viaduct and 4-span 2-story rigid frame viaduct

- R4 (Seismically retrofitted): undamaged
- R1 to R3 (Not yet seismically retrofitted): 1st-story beams and end-joints damaged (and repaired partly by grouting)

No. 2 Yachi BL

The catenary pole above the scaffolding on the left of this photo had been replaced.

Broken catenary pole

No. 2 Yachi BL

The 1st-story transverse beam: X-shaped diagonal cracking

Diagonal cracks were not observed on R3 on the facing side. X-shaped diagonal cracks were found on R2 on the other side.

No. 2 Yachi BL

R2 1-story transverse beam: X-shaped diagonal cracking

No. 2 Yachi BL

R2 1st-story transverse beam: X-shaped diagonal cracking

No. 2 Yachi BL

R2 1st-story transverse beam: X-shaped diagonal cracking

 No. 2 Yachi BL R2 1st-story transverse beam: fine diagonal cracking	 No. 2 Yachi BL R2 1st-story transverse beam: fine diagonal cracking
 No. 2 Yachi BL R1 beam-column joint between 1st-story column and transverse beam: flexural cracking	

 No. 2 Yachi BL R3 North-end column: damaged (and repaired) Joint: repaired by restoring the reduced cross-sectional area with grouting of the cracks 2-story column: cracks grouted with resin	 No. 2 Yachi BL R3 intermediate column at North-end: cracks found Diagonal cracks developed on the surface of the intermediate column in the longitudinal direction.

11) No. 3 Odagi BL (Partly seismically retrofitted after damage) around the 433.669-km mark

- R1 and R2 (Seismically retrofitted after damage): undamaged
- R3 (Not yet seismically retrofitted; cracks grouted after damage): cracks found.
- R6 and R7 (Not yet seismically retrofitted): damaged (and repaired)
- R4, R5, R8 and R9 (Not yet seismically retrofitted): undamaged

<table>
<tr>
<td> 
No. 3 Odagi BL
R7: Top column end damaged. Underwent emergency repairs.</td>
<td> 
No. 3 Odagi BL
R7: Top column end damaged. Underwent emergency repairs.</td>
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<td> 
Unusable rebars were cut out and replaced with new steel reinforcement.</td>
<td> 
R7: Base of damaged column surface after the work of restoring column’s cross-sectional area was completed (1.7 m below the ground surface)
Minor flexural cracking occurred. The top of the footing beam can be seen.</td>
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Details of longitudinal-facing surface of damaged intermediate column

Narrow diagonal cracks developed.

Closeup of the photo to the left

Narrow diagonal cracks developed.

R3: Traces of cracks repaired by grouting were cracked.

R3: Closeup of damage in photo at left

R3: The other side of the column shown above

No. 3 Odagi BL
R1 and R2 (Seismically retrofitted after damage): undamaged

12) No. 1 Kitakamigawa Bridge (Partly seismically retrofitted) around the 408.700-km mark

- Of the cylindrical bridge piers that had not yet undergone seismic retrofitted, only one pier was damaged.

No. 1 Kitakamigawa Bridge

18P: Repair works were carried out by grouting the cracks and restoring the reduced cross-sectional area.

The cylindrical bridge piers in the foreground and behind are 18P and 17P, respectively. Shear cracking occurred near the welded place. Emergency repair work was being carried out.

No. 1 Kitakamigawa Bridge

P18: Repair works were carried out by grouting the cracks and restoring the reduced cross-sectional area.

Detail visible behind the protective sheeting. (The work of restoring the reduced cross-sectional area was being carried out by grouting the cracks and filling the forms with non-shrinkage mortar.)

	
No. 1 Kitakamigawa Bridge 17 P: Minor cracks near the welded place	No. 1 Kitakamigawa Bridge 17P: Minor cracks (Closeup of the photo to the left)

3. Tohoku Expressway (between Morioka IC and Ichinoseki IC)

1) Kitakamigawa bridge on the Kamaishi Expressway

- Undamaged

Kitakamigawa Bridge on the Kamaishi Expressway
Twin main-girders PRC slab: undamaged

Kitakamigawa Bridge on the Kamaishi Expressway
Main girder end

Kitakamigawa Bridge on the Kamaishi Expressway
Bearings on bridge pier

2) Miyanome Bridge on the Kamaishi Expressway

- Undamaged

	
Miyanome Bridge on the Kamaishi Expressway Undamaged	Miyanome Bridge on the Kamaishi Expressway Girder end is integrated with abutment. Light fill is used at the back of the abutment

3) Toyosawagawa Bridge on the Tohoku Expressway

- Undamaged (but peeled paint film at a gusset)

Toyosawagawa Bridge on the Tohoku Expressway: undamaged

Toyosawagawa Bridge on the Tohoku Expressway: bridge pier skewed with respect to the bridge centerline

Toyosawagawa Bridge on the Tohoku Expressway: support point moved due to earthquake

Toyosawagawa Bridge on the Tohoku Expressway: peeled paint film on a gusset plate above the support point on the bridge pier.

(Minor damage: peeling was observed only above the support point and not in other places.)

4) Repairs to expressway pavement

Cracked pavement (minor damage)

Cracked pavement (minor damage)

4. JR Tohoku line (between Morioka and Hanamaki Stations)

Near railway crossing around Iwate Iioka Station on the JR Tohoku line

Despite some disruption to services, this train was running as usual (at 30-minute intervals). The survey team used this local line for transport.

Near railway crossing around Iwate Iioka Station on the JR Tohoku line

5. National Road No. 4 and local roads

Iide Bridge on National Road No. 4

The fill behind the abutment settled, causing a difference in road level. Emergency repair work had been completed.

Iide Bridge on National Road No. 4

Iide Bridge on National Road No. 4

The fill behind the abutment settled, causing a difference in road level.

Iide Bridge on National Road No. 4

The fill behind the abutment settled, causing a difference in road level.

Farm road passing under Prefectural Road No. 205

The culvert was displaced and the pavement had cracked.

Cracked pavement in photo to the left

Precast three-hinge tunnel

(Near Miyanome Bridge on the Kamaishi Expressway): undamaged