

## Summary of the Field Survey on the damage of bridges in the 2011 off the Pacific Coast of Tohoku Earthquake

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**ABSTRACT:** The 2011 off the Pacific Coast of Tohoku Earthquake occurred in Tohoku Province on March 11, 2011. JMA seismic intensity 7 was recorded in Kurihara city. Damage of some bridges which were located on the coast were developed by great tsunami. After the earthquake, the authors conducted investigative research into the typical bridge damage that occurred. Based on the field investigation, damage of some typical bridges are presented in this report.

**Key Words:** Field damage investigation, damage of bridges and buildings, Tsunami

### INTRODUCTION

The off the Pacific Coast of Tohoku Earthquake (Mw9.0) occurred in Tohoku Province (including Tokyo Metropolitan area), Japan, at 14:46 on March 11, 2011. The number of victims and missing people was nearly 20,000. JMA seismic intensity 7 was recorded in Kurihara city. Damage of some bridges which were located on the coast were developed by great tsunami. On the Kesen Bridge which is located in Rikuzentakata city, the superstructure washed-away by tsunami. And the Utatsu Bridge which is located in Minamisanriku town, the superstructure also washed-away.

After the earthquake, the authors of this paper conducted investigative research into the typical bridge damage that occurred. And we had three times investigations in the flooding regions. We conducted first field-damage investigation of bridges and buildings, railway in Iwate and Miyagi prefecture on March 16-21, 2011. Second field-damage investigations were on March 31-April 5, 2011. And third field-damage investigations were on October 10-13, 2011.

In the investigation, several individual surveys were conducted. Based on the field investigation, damage of some typical bridges are presented in this report. It should be noted that since the investigation was conducted without prior information on design drawings and analysis, it is highly possible that the authors made incorrect interpretations of the failure mechanism.

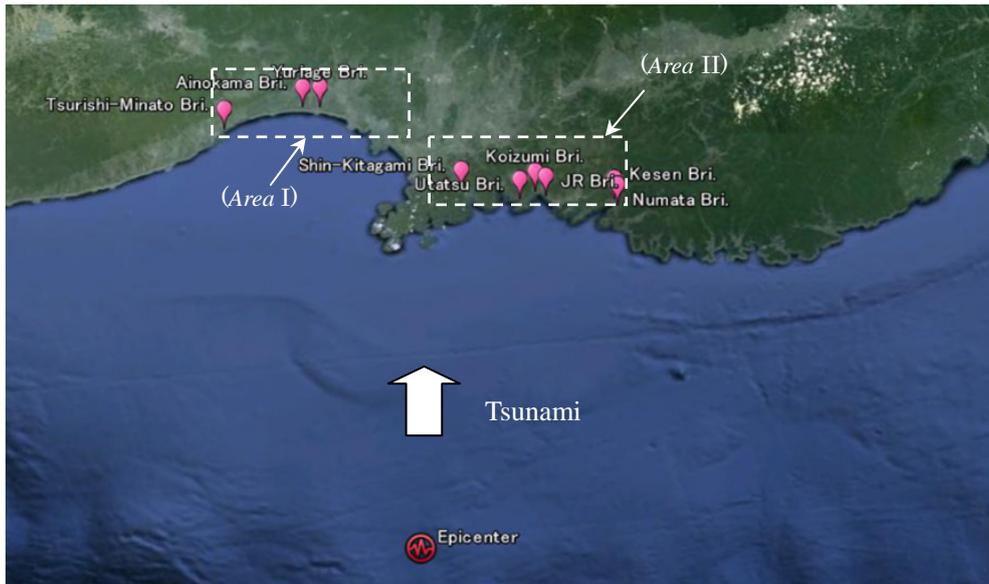


Fig. 1 Relationship between Epicenter and damage of some typical bridges

Table 1 Schedules of survey

No	Date	Site	
		Prefecture	Typical of City
1	March 15-21	Iwate	Rikuzentakata, Ofunato
		Miyagi	Iwanuma, Ishinomaki, Kesenuma Minamisanriku, Onagawa
2	March30-April 4	Iwate	Kamaishi, Yamada, Miyako Rikuzentakata
		Miyagi	Minamisanriku, Onagawa Rikuzen-Koizumi
3	Octorber10-13	Iwate	Kamaishi, Ryoishi, Touni Rikuzentakata
		Miyagi	Iwanuma, Ishinomaki, Kesenuma Minamisanriku, Watari
		Fukushima	Soma, Shinchi

### OUTLINE OF THE OFF THE PACIFIC COAST OF TOHOKU EARTHQUAKE

The earthquake of moment magnitude M9.0 occurred off Sanriku coast at 14:26 JST on March 11, 2011 and caused tremendous damage of collapse and washed-away of bridges, buildings, houses and other structure by ground motion and tsunami in the Pacific coast of eastern Japan, including prefecture of Iwate, Miyagi, Fukushima, Ibaraki and Chiba. The earthquake has recorded the seismic intensity 7, highest in the Japan Meteorological Agency scale, in north of Kurihara city (Miyagi pref.).

Fig.1 shows relationship between epicenter and typical damage of bridges. After the 2011 Tohoku earthquake, many bridges were damaged and washed-away by tsunami. In the Kesen Bridge where is located in Rikuzentakata City, superstructure washed-away by tsunami. Koizumi Bridge also washed-away.

## OUTLINE OF FIELD SURVEY

After the earthquake, the authors of this paper conducted investigative research into the typical bridge damage that occurred. And we had three times investigations in the flooding regions. Table 1 shows schedules of survey and investigation area. We conducted first field-damage investigation of bridges and buildings, railway in Iwate and Miyagi prefecture on March 16-21, 2011. Second field-damage investigations were on March 31-April 5, 2011. Third field-damage investigations were on October 10-13, 2011. In the investigation, several individual surveys were conducted.

## DAMAGE OF BRIDGES

We investigated damage of bridges in Iwate, Miyagi and Fukushima pref. Only typical damage (as shown in Fig.2) is presented in this chapter. Table 2 shows typical damage of bridges by tsunami. In this report, damage of nine typical bridges are presented



(a) Area-I (Generally coastline, Fukushima and Miyagi)



(b) Area-II (Saw-toothed coastline, Miyagi and Iwate)

Fig. 2 Map of typical bridges

Table 2 Typical damage of bridges

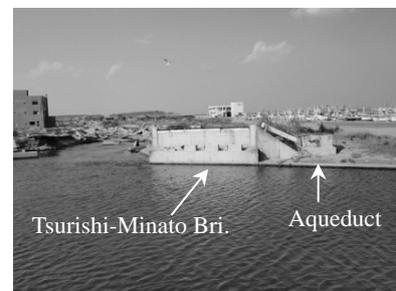
No	Bridge	Prefecture	Type
1	Tsurishi-minato (pc)	Fukushima	Generally coastline
2	Ainokama (steel)	Miyagi	Generally coastline
3	Yuriage (pc)	Miyagi	Generally coastline
4	Shin-kitagami (steel, truss)	Miyagi	Saw-toothed coastline
5	Utatsu (pc)	Miyagi	Saw-toothed coastline
6	Koizumi (steel)	Miyagi	Saw-toothed coastline
7	JR-line Bri. (kesenuma-line, pc)	Miyagi	Saw-toothed coastline
8	Kesen (steel)	Iwate	Saw-toothed coastline
9	Numata (pc)	Iwate	Saw-toothed coastline



(a)The view of bridge

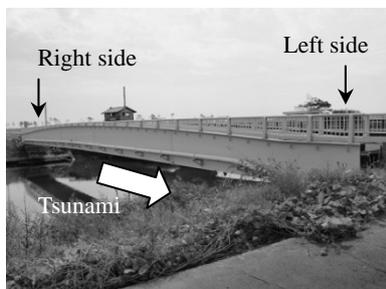


(b) Superstructure



(c) Abutment

Photo 1 Tsurishi-Minato Bridge



(a)The view of bridge



(b) Superstructure (left side)

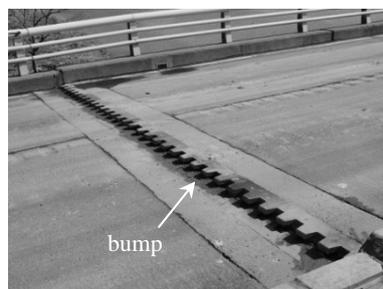


(c) Superstructure (Right side)

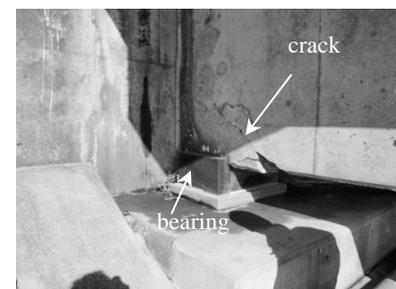
Photo 2 Ainokama Bridge



(a)The view of bridge



(b) Joint

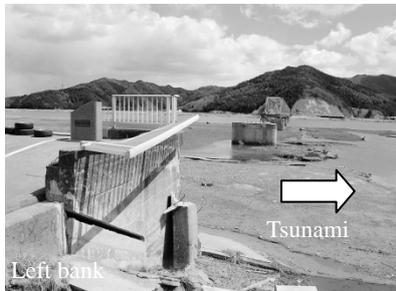


(c) Superstructure and bearing

Photo 3 Yuriage Bridge

(1) Generally coastline (from Fukushima to Miyagi pref.)

Tsurishi-Minato Bridge is located in Shinchi town (Fukushima prefecture). Photo 1 shows damage of bridge after tsunami. Superstructure was made with PC, and the type was single beam. We see from the Photo 1 (b) that superstructure washed-away. Aqueduct which was located next to the Tsurishi-Minato bridge, also washed-away.



(a) The view of bridge



(b) Superstructure  
Photo 4 Shin-kitagami Bridge



(c) Pier



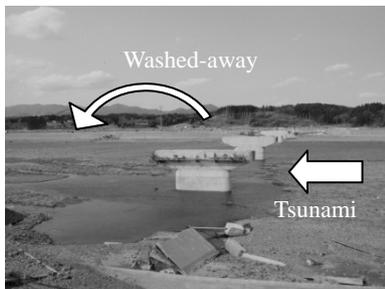
(a) The view of bridge



(b) Superstructure  
Photo 5 Utatsu Bridge



(c) Pier



(a) The view of bridge



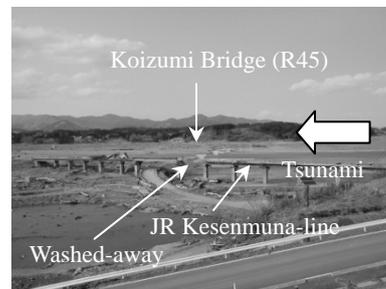
(b) Superstructure



(c) Pier



(d) Abutment



(e) The view of JR Bridge

Photo 6 Koizumi Bridge

Ainokama Bridge is located in Iwanuma city (Miyagi prefecture). Photo 2 shows damage of bridge after tsunami. Superstructure was made with steel, and the type was single beam. We see from the Photo 2 that superstructure was moved. Relative displacement of left side was about 1.0m, and other side was about 0.2m.

Yuriage Bridge is located in Natori city (Miyagi prefecture). Photo 3 shows damage of bridge after tsunami. The structure is 541.7m long and consists of three-span continuous PC-Box type girder bridge with PC-T type girder approach bridges of seven spans. And the bridge supported by steel bearings as shown in Photo 3 (c). We see from the Photo 3 (b and c) that joint and girder was damaged by strong ground motion. But the structure did not wash-away by tsunami.

(2) Saw-toothed coastline (from Miyagi to Iwate pref.)

Shin-kitagami Bridge is located in Ishinomaki city (Miyagi prefecture). Photo 4 shows damage of bridge after tsunami. Superstructure was made with steel, and the type was truss beam. We see from the Photo 4 (b) that superstructure (two-spans) washed-away.

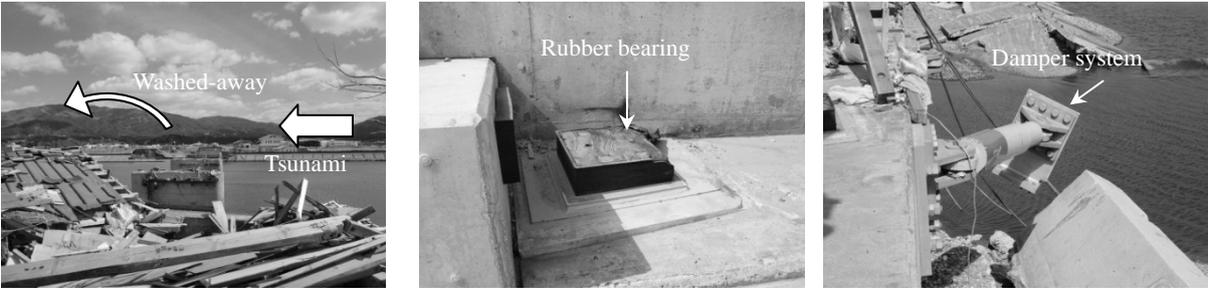
Utatsu Bridge is located in Minami-sanriku town (Miyagi prefecture). Photo 5 shows damage of bridge after tsunami. The structure is about 304m long, and the superstructure was made with PC, and the type was PC-T beam. We see from the Photo 5 (b) that superstructure (eight-spans) washed-away.

Kozumi Bridge is located in Kesennuma city (Miyagi prefecture). Photo 6 shows damage of bridge after tsunami. The structure is 182m long, and the superstructure was made with steel, and the type was continuous girder. We see from the Photo 6 (b) that superstructure (six-spans) washed-away. And one pier (P3) was collapsed and washed away. The boundary of bearing was movable. This bridge was retrofitted by damper system as shown in Photo 6 (d). JR-line viaduct that is located next to the Koizumi Bridge, also washed-away by tsunami as shown in Photo 6 (e).

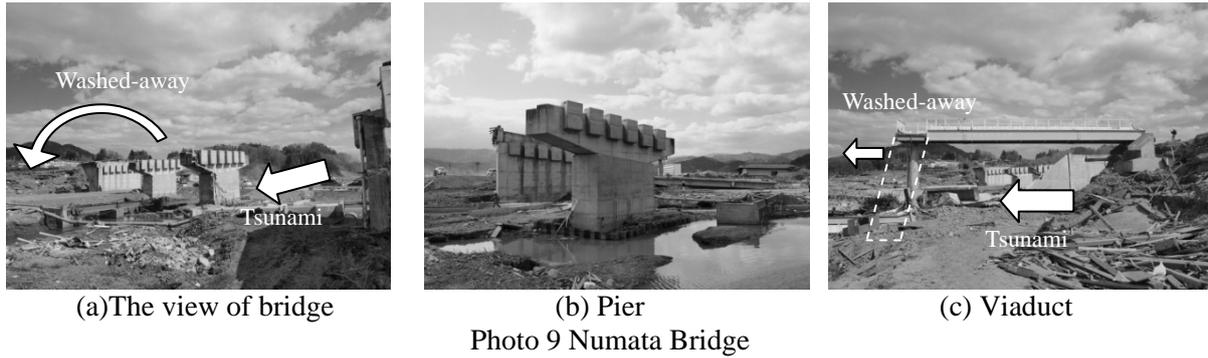
JR-line Bridge is located in Kesennuma city (Miyagi prefecture). Photo 7 shows damage of bridge after tsunami. The superstructure was made with PC, and the type was single beam. We see from the Photo 7 (b and c) that superstructure (three-spans) washed-away, and two piers were collapsed.



(a)The view of bridge (b) Superstructure (c) Pier  
Photo 7 JR-line Bridge (Kesennuma-line)



(a)The view of bridge (b) Rubber bearing (c) Damper  
Photo 8 Kesen Bridge



Kesen Bridge is located in Rikuzentakata city (Iwate prefecture). Photo 8 shows damage of bridge after tsunami. The structure is 181.5m long, and the superstructure was made with steel. And the bridge supported by rubber bearings as shown in Photo 8 (b). We see from the Photo 8 that superstructure (all-spans) washed-away. This bridge was retrofitted by damper system as shown in Photo 8 (c).

Numata Bridge is located in Rikuzentakata city (Iwate prefecture). Photo 9 shows damage of bridge after tsunami. The structure is about 65m long, and the superstructure was made with PC. We see from the Photo 9 that superstructure (all-spans) washed-away. Viaduct that is located next to the Numata Bridge, also washed-away by tsunami as shown in Photo 9 (c).

**CONCLUSIONS**

After the off the Pacific Coast of Tohoku Earthquake, the authors of this paper conducted investigative research into the typical bridge damage that occurred. And we had three times investigations in the flooding regions.

From the field survey, the conclusions have been stated below:

- (1) In the Tsurishi-minato Bridge, superstructure washed-away. But Abutment was not collapse. And superstructure of aqueduct also washed-away.
- (2) In the Ainokama Bridge, superstructure was moved by tsunami.
- (3) In the Yuriage Bridge was damaged superstructure, bearing and joint by strong ground motion. But it was not washed-away.
- (4) Some bridges where are located on saw-toothed coastline, superstructure washed-away by tsunami. In the Koizumi Bridge, pier (P3) was collapse and washed-away.

Finally, it should be noted that since the investigation was conducted without prior information on design drawings and analysis, it is highly possible that the authors made incorrect interpretations of the failure mechanism.