Preliminary Report of the Damage by the 2022 Off Fukushima Prefecture Earthquake Mj7.4, Japan

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Key Facts
- Hazard Type: Earthquake
- Date of the disaster: March 16th, 2022
- Location of the survey: Fukushima and Miyagi prefectures, Japan
- Date of the field survey: March 18th and 19th, 2022
- Survey tools: Digital Camera, GPS
- Key findings:
  (1) The superstructure collided against the western side abutment in the Date bridge.
  (2) The bearing pin was unfastened in the Showa Bridge.
  (3) The steps of intermediate piers can be confirmed in the Danzaki bridge.
  (4) The viaduct tilt due to Shear failure of columns was observed in Kunimi Town.

Key Words: *Offshore the Fukushima Prefecture Earthquake, Geotechnical damage, Damage to bridges, Damage to Shinkanssen structure*

1. INTRODUCTION

At 23:36 on March 16, 2022, a Mj7.4 earthquake occurred off the coast of Fukushima Prefecture. The Japan Meteorological Agency (JMA) estimates that it was an aftershock of the 2011 off the Pacific coast of Tohoku earthquake. The epicenter of this earthquake was at 37°41'8" N, 141°37'3" E, and the depth of the epicenter was about 57 km. It was a fault-type earthquake with a pressure axis in the northwest-southeast direction. The maximum intensity of this earthquake was 6+ observed in Tome City, Zao Town, Kunimi Town, Soma City, and Minami-soma City. In particular, a rather large peak acceleration of 1232.7 cm/s^2 was observed at KiK-net Kawasaki (MYGH07). The JMA announced that long-period seismic motion class 4 was observed in northern Miyagi Prefecture.

About one year before this earthquake, a similar Mj7.3 earthquake occurred off the coast of Fukushima Prefecture. Table 1 shows a summary of these two earthquakes and epicenters are shown in Figure 1: their epicenters are close to each other and their magnitudes and maximum seismic intensities are almost equal.

We conducted a survey of earthquake damage in Fukushima and Miyagi prefectures on March 18 and 19,

2022. We focused on structural damage of the viaducts and bridges of the Tohoku Shinkansen (Tohoku bullet train), and road bridges crossing the Abukuma River.

In this report, ground motions during the 2021 and the 2022 earthquakes are compared and findings of our survey of the seismic damage of the structures are shown.

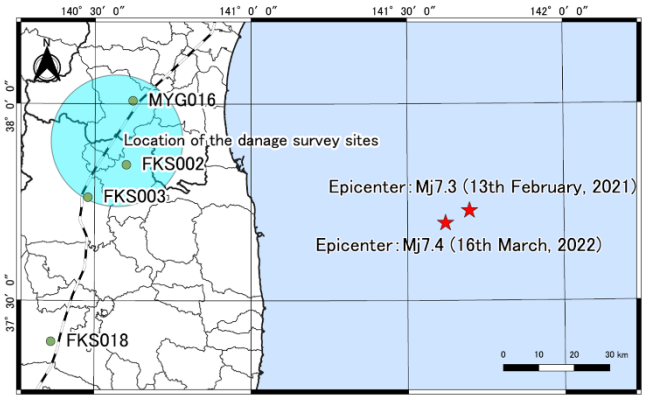
2. STRONG GROUND MOTION RECORD NEAR THE TOHOKU SHINKANSEN IN THE NAKADORI AREA OF FUKUSHIMA PREFECTURE

We compare the ground motions observed near the Tohoku Shinkansen during the two earthquakes.

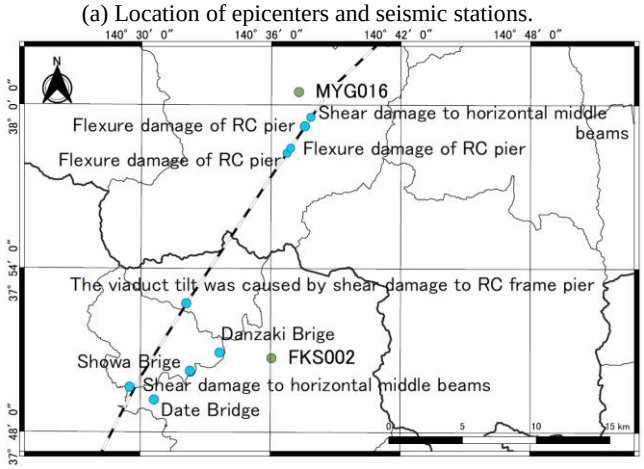
Figure 1 shows the location of the K-NET seismic stations operated by NIED[1] near our survey site. K-NET Shiroishi(MYG016) is close to the location where a Shinkansen bullet train was derailed. K-NET Yanagawa(FKS002) is located near the road bridges crossing the Abukuma River.

Figure 2 show the acceleration time histories observed at the four seismic stations during the two earthquakes. They are rotated to the directions perpendicular to the Shinkansen lines close to the seismic stations (Table 2). At MYG016 and FKS002, the acceleration observed in the 2022 earthquake was larger than in the 2021 earthquake; at K-NET Fukushima (FKS003), the observed acceleration was similar for the 2021 and the 2022 earthquakes; at K-NET Koriyama(FKS018), the acceleration observed in the 2022 earthqu¸ake was smaller than in the 2021 earthquake. At FKS002, peak acceleration is 709 cm/s^2 in the direction perpendicular to the Tohoku shinkansen line.

Figure 3 shows the acceleration response spectra of ground motions shown in Figure 2 for the 2022 earthquake. Among four seismic staion, response spectra for FKS003 is the largest in the long period range (1.0 to 2.0 sec.) and that for FKS002 is the largest in the short period range (shorter than 0.2 sec).



(a) Location of epicenters and seismic stations.



(b) Location of damaged structures surveyed.

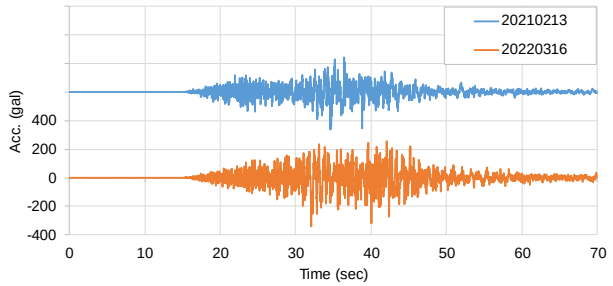
Fig.1 Location of the damage survey sites and seismic stations with the focal mechanism of the 2021 and the 2022 earthquake[2), 3)].

Table.1 Outline of the earthquakes of the 2021 and the 2022 that occurred at off Fukushima prefecture.

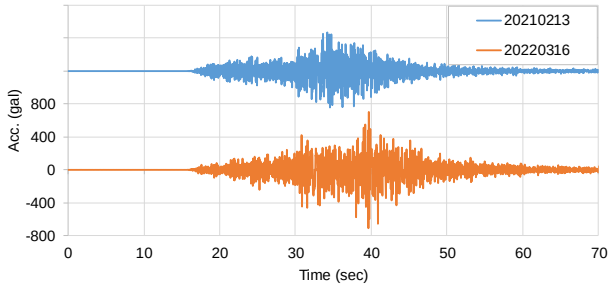
Date	February 13rd 2021		March 16th 2022	
Time	23:07		23:36	
Epicenter	37°43.7'N, 141°41.9'E		37°41.8'N, 141°37.3'E	
Epicenter depth	55km		57km	
Magnitude	7.3		7.4	
Maximum seismic intensity	6+		6+	
Areas of maximum seismic intensity	Soma City	Shinchi Town	Tome city	Zao Town
			Kunimi Town	Soma City
	Kunimi Town	Zao Town	Minamisoma City	

Table.2 Directions perpendicular to the Shinkansen viaducts near the four seismic stations.

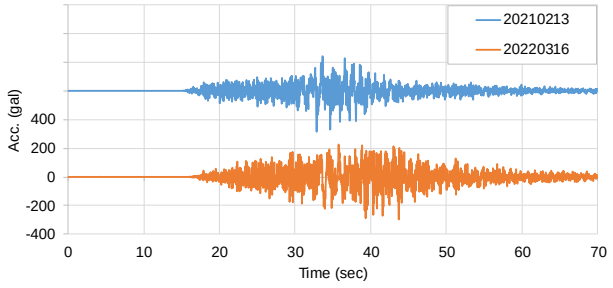
Seismic stations	Directions perpendicular to the Shinkansen viaducts
MYG016	N131°E
FKS002	N99°E
FKS003	N100°E
FKS018	N99°E



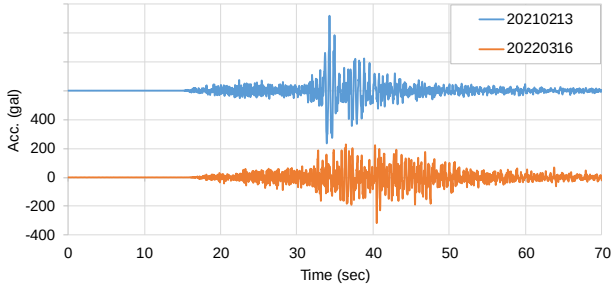
(a) K-NET Shiroishi (MYG016)



(b) K-NET Yanagawa (FKS002)



(c) K-NET Fukushima (FKS003)



(d) K-NET Koriyama (FKS018)

Fig.2 Comparison of acceleration waveforms observed at four K-NET stations near the Tohoku Shinkansen line during the 2021 and 2022 earthquakes: rotated to the directions perpendicular to the Shinkansen axis (Table 2).

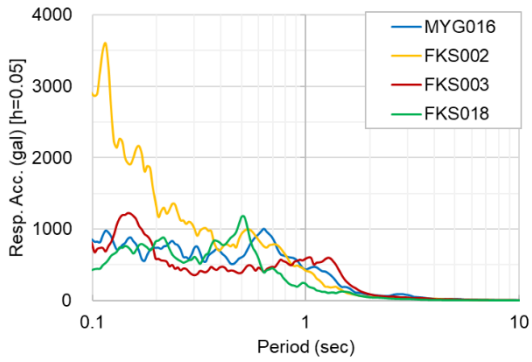


Fig.3 Acceleration response spectra (h=0.05) of the ground motion shown in Figure 2 for the 2022 earthquake.

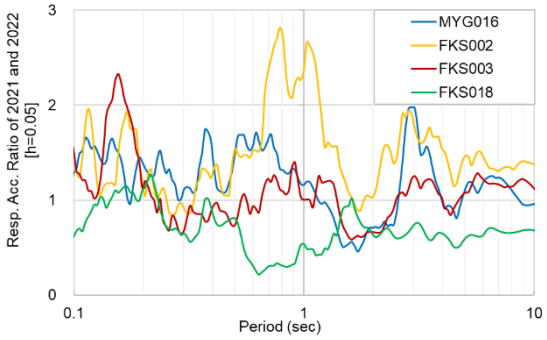


Fig.4 Ratios of the acceleration response spectra of the 2022 earthquake to the 2021 earthquake for the ground motions shown in Figure 2.

Figure 4 shows the ratios of the acceleration response spectra of the 2022 earthquake to the 2021 earthquake for the ground motions shown in Figure 2. The response spectra of the 2022 earthquake tends to be larger except for FKS018. At FKS002, the response spectrum of the 2022 earthquake is about 2.5 times larger than that of the 2021 earthquake around the natural period of 1 second. At MYG016, the response spectrum of the 2022 earthquake is larger than the 2021 earthquake at many natural periods. At FKS003, the 2022 earthquake is prominent on the short period side. At FKS018, the response spectrum of the 2022 earthquake is smaller than that of the 2021 earthquake.

3. SEISMIC DAMAGE OF BRIDGES

(1)Date Bridge

Date Bridge is located at 37°49'11.2"N, 140°30'37.6"E, crossing the Abukuma River in the east to west direction. It is a four-span truss bridge completed in 1967. In Date Bridge, the superstructure collided against the western side abutment. Photo 1(a) shows a large step occurred on the west side. Photo 1(b) shows a large clearance occured at the expansion joint and the broken bearing on the east side. Emergency restoration of the bridge is expected to take from two to three years, and the bridge replacement is also considered[4]. When our survey was conducted, the damage to the soil behind the abutment and surrounding ground was not observed. Therefore, the damage to Date Bridge is considered to be caused by inertial forces during the earthquake.

(2) Showa Bridge

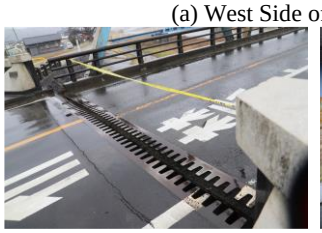
Showa Bridge is located at 37°50'14.7"N, 140°32'17.0"E, crossing Abukuma River in the east to west direction. It is a four-span truss bridge completed in 1993, and is equipped with a bridge fall prevention system.

At the time of our survey, there was no apparent damage in the ground behind the abutment or the surrounding ground, but cracks was appeared in the pavement (Photo 2). In addition, the bearing pin was unfastened, as shown in Photo 2(b). The bridge was scheduled to be opened to traffic on March 19, 2022, from the rehabilitation work after the 2021 earthquake, but was closed due to the earthquake damage from the 2022 earthquake.

(3) Danzaki Bridge

Danzaki Bridge is located at 37°50'55.0"N, 140°33'39.0"E, crossing Abukuma River in the east to west direction. It is a seven-span PC simply supported bridge completed in 1961. There was no apparent damage near the abutments, but the step between girder ends and abutment was caused by seismic damage to bearings as shown in Photo 3. In addition, cracks were found on the end of the girder as shown in Photo 3(d). There was no apparent damage on the behind of the abutment and the surrounding ground. Therefore, these damages are considered to be caused by the inertial force from the earthquake ground motion.


(a) West Side of Date Bridge.




(b) East Side of Date Bridge.

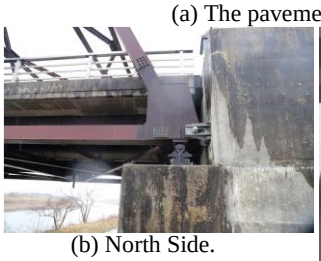
Photo.1 Damage of Date Bridge.**(**37°49'11.2"N, 140°30'37.6"E)

4. DAMAGE TO SHINKANSEN STRUCUTURE

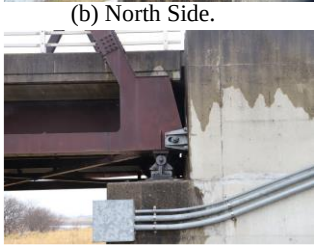
(1) Shear damage to horizontal middle beams of the two-story RC frame

Damage to the transverse beams of the two-story RC frame of the virducts of the Tohoku Shinkansen was observed over a wide area, from Koriyama City, Fukushima Prefecture, to Shiroishi City, Miyagi Prefecture. In particular, significant damage, concrete spalling and rebar exposure, was observed at several viaducts from Date City, Fukushima Prefecture, to Shiroishi City, Miyagi Prefecture (Photo 4, Photo 5). In

(a) The pavement cracked.



(b) North Side.




(c) South side. (d) The bearing pin unfastened.

Pthoto.2 Damage of Showa Bridge.
(37°50'14.7"N, 140°32'17.0"E)

(a) Danzaki Bridge.


(b) Abutments of Danzaki Bridge.


(c) Intermediate Piers. (d) The End of Girder.

Photo.3 Damage of Danzaki Bridge.
(37°50'55.0"N, 140°33'39.0"E)

these areas, the seismic waves were observed to be larger than those of the 2021 earthquake, and the damage to the transverse beams was observed to be significant. In addition, in Shiroishi City, Miyagi Prefecture, the damage that considered to be developed from repair scars of the past earthquake was observed.

(2) Flexure damage of RC pier

In the area from Date City to Shiroishi City, some flexure damage in the RC frame piers were observed. In the damaged columns, the longitudinal bars buckled, and the concrete was spalling (Photo 6, Photo 7, Photo 8). In particular, the survey revealed that the number of damaged columns was higher near Shiroishi City, Miyagi Prefecture than in other areas. However, compared to the number of damaged transverse beams described in (1), the number of damaged columns is small.Furthermore, damage occurred only to columns that had not been seismically retrofited; no damage occurred to columns that had been seismically retrofitted with steel jacketing.

Photo.4 Shear damage to horizontal middle beams in Date City, Fukushima Prefecture. (37°49'30"N, 140°29'39"E)

Photo.5 Shear damage to horizontal middle beams in Shiroishi City, Miyagi Prefecture.(37°59'33"N, 140°37'50"E)

Photo.6 Flexure damage of RC pier in Shiroishi City, Miyagi Prefecture(Saikawa BV).(37°58'14"N, 140°36'44"E)

Photo.7 Flexure damage of RC pier in Shiroishi City, Miyagi Prefecture.(37°58'25"N, 140°36'54"E)

(3) Shear damage to RC pier

Shear failure of columns was observed in Kunimi Town, Fukushima Prefecture. The photographs show significant shear cracks in the columns, indicating that the loss of the capacity to support the axial load of some columns caused the viaduct to tilt (Photo 9). For the viaduct, the damage occurred only on the columns that were not seismically retrofitted; the columns above the middle beams were not damaged because they had been seismically retrofitted with steel jacketing.

Photo 8 Flexure damage of RC pier in Shiroishi City, Miyagi Prefecture.**(**37°59'13"N, 140°37'33"E)

Photo 9 The viaduct tilt was caused by shear damage to RC frame pier in Kunimi Town, Fukushima Prefecture. **(**37°52'43"N, 140°32'06"E)

5. SUMMARY

This report shows our survey of the seismic damage to the various structures in Fukushima and southern Miyagi prefectures during the 2022 earthquake with some analysis of observed ground motions around the survey sites. We surveyed damege on bridges crossing the Abukuma River, the viaducts of the Tohoku Shinkansen, and bridges of the Tohoku Shinkansen. At the Date Bridge, large steps and separation and the collision of the superstructure to an abutment were observed. At the Showa Bridge, bearing pins were unfastened. At the Danzaki Bridge, steps on the intermediate piers were observed. For the Tohoku Shinkansen railway structures, we observed shear damage to the horizontal middle beams of the two-story RC viaduct and shear and flexure damage to the RC piers.

As described above, the survey revealed several issues regarding the seismic safety of civil engineering structures to be taken seriously.

ACKNOWLEDGMENT: In this report, we have used the seismic motion records published by NIED.

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