Preliminary Report of the Damage by the 2021 Off Fukushima Prefecture Earthquake Mj7.3, Japan

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Key Facts
- Hazard Type : Earthquake
- Date of the disaster : February 13th, 2021
- Location of the survey : Fukushima and Miyagi prefectures, Japan
- Date of the field survey : February 15th and 16th, 2021
- Survey tools : Digital Camera
- Key findings:
  (1) Minor damage due to soil liquefaction and ground deformation were found in Yamamoto Town and Soma Port.
  (2) Damage, such as road pavement cracks, cracks around abutment and suspected liquefication in Soma Overpass Bridge and Soma East Bridge are reported.
  (3) Cracks and spalling due to shear deformation in horizontal beams of the frame piers of the Shinkansen viaduct near to Shiroishi Zao station were found.
  (4) Damage to buildings was not severe compared to the measured strong ground motions.

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

1. INTRODUCTION

At 23:07 on February 13th, 2021, an earthquake of Mj7.3 occurred off the coast of Fukushima Prefecture. Japan Meteorological Agency (JMA) estimated that it was an aftershock of the 2011 off the Pacific coast of Tohoku earthquake. The epicenter of this earthquake is located at 37.7N,141.8E, and the depth of the epicenter is about 55 km, fault-type earthquake with a pressure axis in the WNW-ESE direction. The largest seismic intensity of this earthquake, 6+, was observed in Soma City, Shinchi Town, Kunimi Town, and Zao Town. Substantial large peak ground acceleration of 1432 cm/s^2 was observed in KiK-net Yamamoto station (MYGH10).

Moreover, the class-4 long-period ground motion was observed by JMA in Nakadori, Fukushima Prefecture. The high-speed train, Tohoku Shinkansen, was stopped for 10 days due to damage of utility poles on the railway viaducts. The Joban Expressway (between Soma IC and Watari IC) was closed due to the collapse of a cut slope. In Yamamoto Town, where large surface acceleration was observed, water was cut off for six days. The authors conducted an earthquake damage survey in Fukushima and southern Miyagi prefectures on February 15 and 16. This

report summarized characteristics of ground motions, geotechnical and structural damage.

2. STRONG GROUND MOTION RECORD AT DAMAGE INVESTIGATION AREA

Figure 1 shows the seismic stations of the NIED[1] near the area of this earthquake damage survey. These stations, KiK-net Yamamoto (MYGH010), K-NET Soma (FKS001), K-NET Fukushima (FKS003), K-NET Shiroishi (MYG016) and K-NET Koriyama (FKS018), are installed near our earthquake damage survey sites. Figure 2 shows the distribution of the epicenters of earthquakes that occurred from 1997 to 2021 off the Pacific Ocean, including off Fukushima Prefecture. The epicenter of the 2021 earthquake is closer to the Japanese archipelago than that of 2011. Figure 3 shows the surface acceleration time histories of these five stations. Figure 4 shows the acceleration response spectra and velocity response spectra of these five stations. At MYGH10, located 84 km from the epicenter, a substantial acceleration of 1421 cm/s^2 was observed in the NS component. Figure 5 shows a comparison of the acceleration time history and acceleration response spectra observed at point MYGH10 for the 2011 Tohoku earthquake and this earthquake. The acceleration is larger than the surface acceleration observed in the 2011 Tohoku earthquake. The maximum velocity response of the earthquakes observed at seismic stations FKS003 and MYGH10 exceeds 100 cm/s per eigen period of 1.5 seconds. In this area (Nakadori Area, Fukushima Prefecture), the class-4 long-period ground motion was observed by JMA.

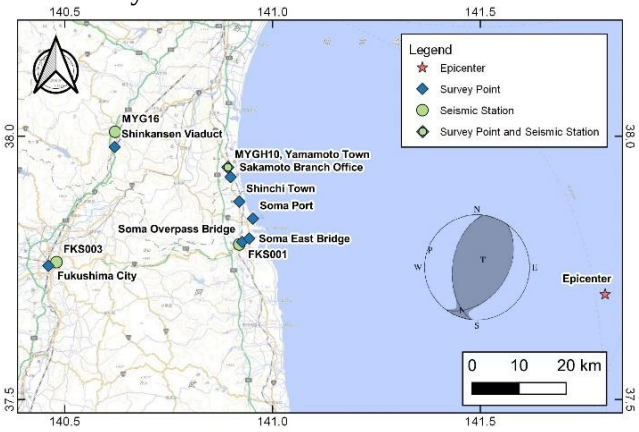


Fig.1 Location of damage survey sites and adjacent seismic stations with focal mechanism of the 2021 earthquake[2].

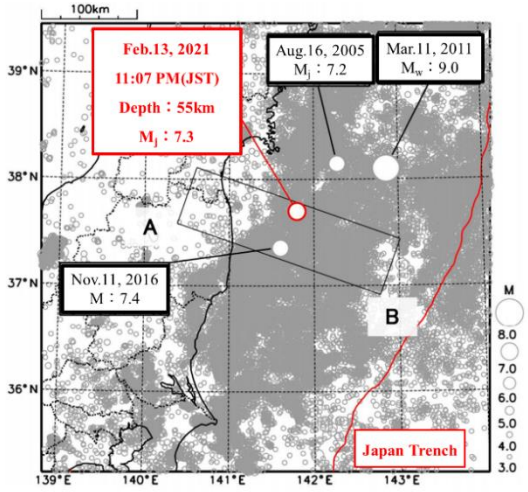


Fig.2 Distribution of epicenters around Off Fukuchima Prefeture region[2].
(Oct. 1,1997-Feb.13,2021, depth=0-150km,Mj≥3.0)

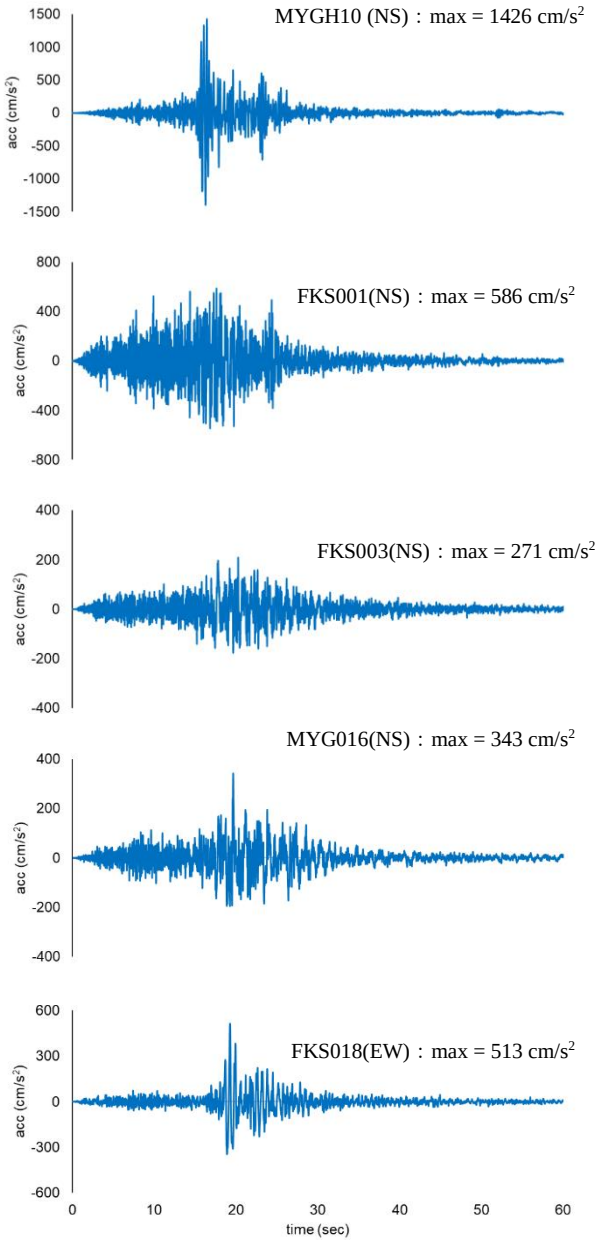
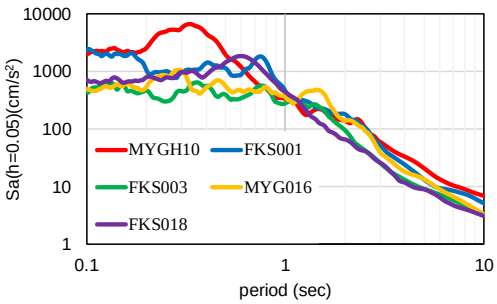
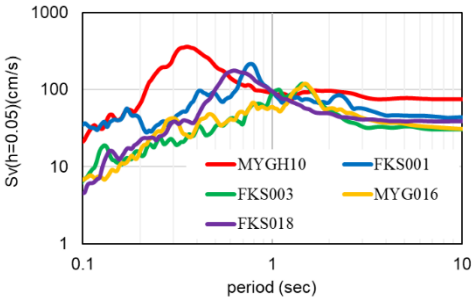


Fig.3 Observed acceleration waveforms.

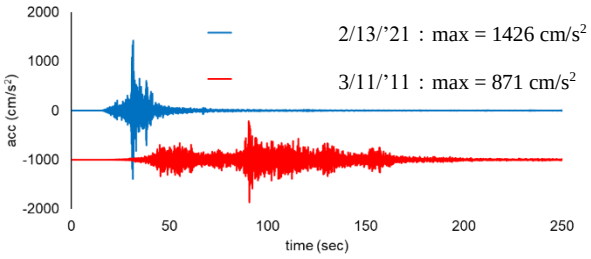


(a) Acceleration response spectra Sa(h=0.05).



(b) Velocity response spectra Sv(h=0.05)

Fig.4 Response spectra Sa and Sv.



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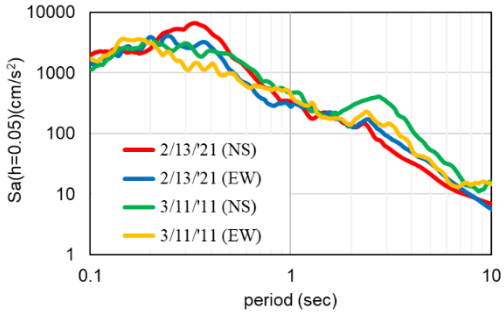

(b) Acceleration response spectra Sa(h=0.05)

Fig.5 Comparison of the 2021 earthquake and the 2011 Tohoku Earthquake observed at MYGH10.

3. GEOTECHNICAL DAMAGE

(1) Sakamoto Branch Office, Yamamoto Town

The 2021 earthquake caused minor geotechnical damage in a residential area in Yamamoto Town, Miyagi Prefecture. After the tsunami in the 2011 Tohoku earthquake, new residential houses and Sakamoto Branch Office of Yamamoto Town were constructed on the reclaimed land that was once paddy fields. Photo 1 shows aerial photos of the affected area taken in 2009 and 2021, respectively. Photos 2 (1) shows the damage observed around the Sakamoto Branch Office. It was observed that the block pavement around the building foundation was deformed. This was due to the settlement of the reclaimed soil, and no deformation was observed at the building that is considered to have a good foundation. In addition, the road pavement at the north of the building had cracks about 5cm-wide running in the transverse direction of the road (Photo 2 (2)).

The area to the northwest of the branch office is a residential area that has existed since before the 2011 Tohoku earthquake. In this area, the 2021 earthquake caused roof tiles of several houses to fall off and block walls to lean in some places (Photos 2 (3)). However, there was no ground deformation-induced damage as in the new residential area, reclaimed after the 2011 earthquake.This clear distinction may be attributed to a difference in dynamic soil response characteristics of the reclaimed and the old districts.

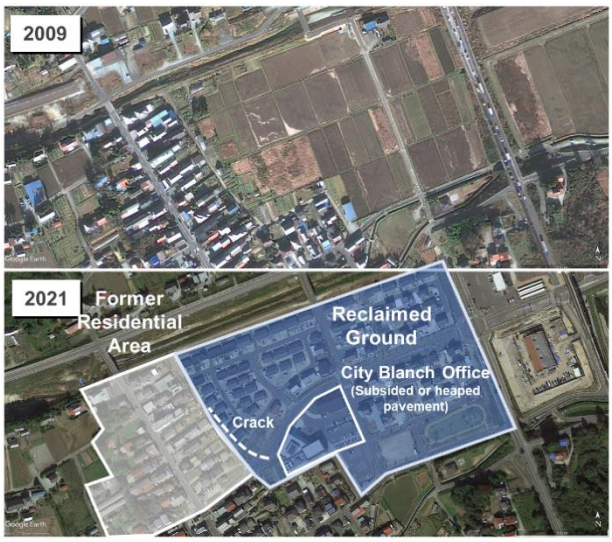

Photo 1 Sakamoto residential area before and after the reclamation (Sattelite Image : Google, ©2021 Maxar Technologies)

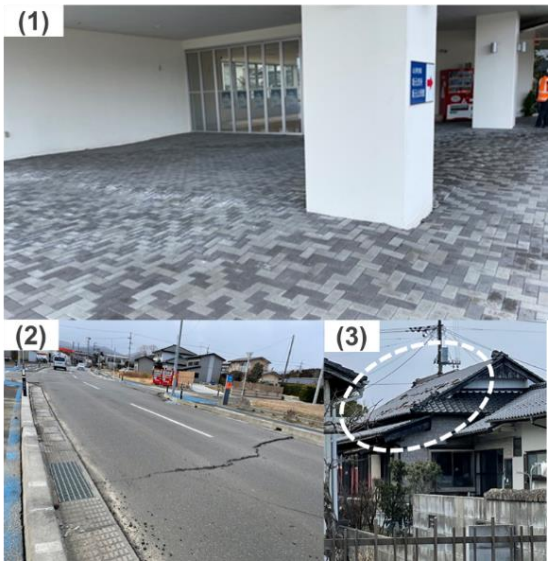

Photo 2 Various damage identified in Sakamoto residential area.

Fig.6 Observed damage map of Soma Port

Photo 3 Liquefaction-induced damage in Soma Port

(2) Soma Port

Photo 3 and Fig.6 show the damaged site of No.2 quay at Soma Port in Fukushima Prefecture. As shown in Photos 3 (1) and (2), the 2021 earthquake caused liquefaction in the ground behind the quay wall and 10 to 20m long cracks with about 15cm opening parallel to the quay. The quay wall's concrete blocks were slightly inclined toward the sea, resulting in about 15 cm step. The 2011 Tohoku earthquake and subsequent tsunami of about 10 meters in height caused significant damage to Soma Port[3]. However, the damage to port facilities caused by the 2021 earthquake was relatively minor and did not significantly disrupt port functions.

4. SEISMIC DAMAGE OF BRIDGES

(1) Soma Overpass Bridge

Soma Overpass Bridge is located at the south of the Soma Station (37°47'58.4"N, 140°55'36.1"E), crossing the Joban Line from southwest to northeast direction. It is a single span steel girder concrete deck bridge with five I shape girders, bridge fall prevention system. It is supported by two abutments supporting the girders with steel bearing. Expansion joints are installed in both sides of the girder to connect with the approaching road. Small step difference can be observed around the joints on both sides, as shown in Photo 4.

Road pavement cracks can be seen near the southwest joint in the abutment side, but not seen around the pavement of the bridges' northeast side. On both sides of the northwest abutment, cracks and damage was found. It can be assumed that the bridge moved toward northwest direction and pressed the northwest abutment, and pulled the southwest abutment, as can be seen in Photo 4.

(2) Soma East Bridge

Soma East Bridge is in the east side of Soma city (37°47'58.4"N, 140°55'36.1"E). It is the bridge of National road No.6 crossing the Utagawa river. The main bridge is a seven span steel girder bridge with rubber bearings.

The locations of damage are marked in Photo 5. It can be seen that most of the damage outlooks are concentrated in the south side of the bridge around abutment A1. The residual shear deformation is observed at the bearing of the girder No. 5 at abutment A1. The damage is also marked by chalk. Road pavement cracks in south of A1 are clear with step difference.

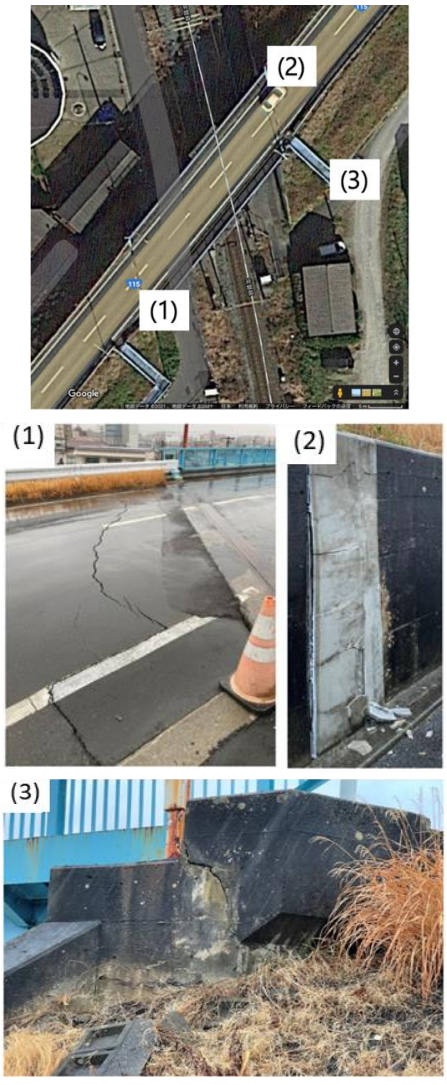

Photo 4 Damage of Soma Overpass Bridge.

Obvious vibration can be felt on standing by when heavy trucks are passing by. Under the P1 and A1, there are suspicious sands piles which may be caused by liquefaction.

From a brief observation, bearings are standing straight without tilting except those in A1. And the scratch marks caused by the two horizontal direction shaking of earthquake were observed in all of them. As been reported in the past, the movement of abutment due to liquefication or nonlinear deformation of grounds may be the reason of the residual displacement on bearings of abutment and the pavement cracks on approaching road.

(3) Shinkansen viaduct

According to the report of Tohoku Broadcasting Company on Feb. 18, 2021[4], ten piers and twenty poles were damaged at the two locations. We visited one of them, south of Shiroishi Zao Station (37°58'46.9"N 140°37'11.6"E).

Typical shear damage can be seen in the horizontal middle beam in the frame of transvers direction of the continued two-direction frames as shown in Photo 6. Cover concrete spalling and steel bars expossion can be seen in Photo 6 (3). Similarly, other horizontal beams of near by frame piers also developed shear cracks, even without spalling of cover concrete.

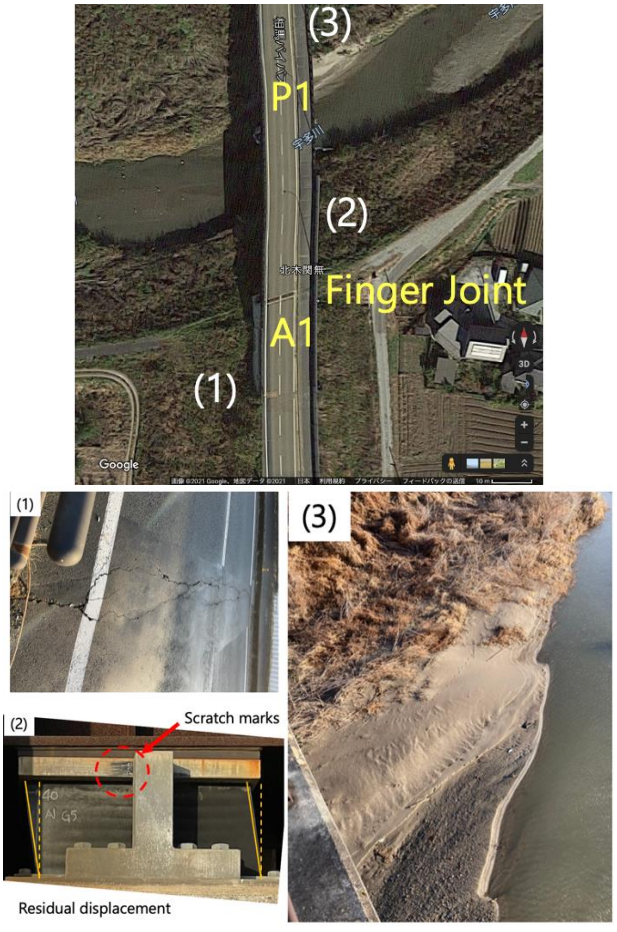

Photo 5 Damage of Soma East Bridge.

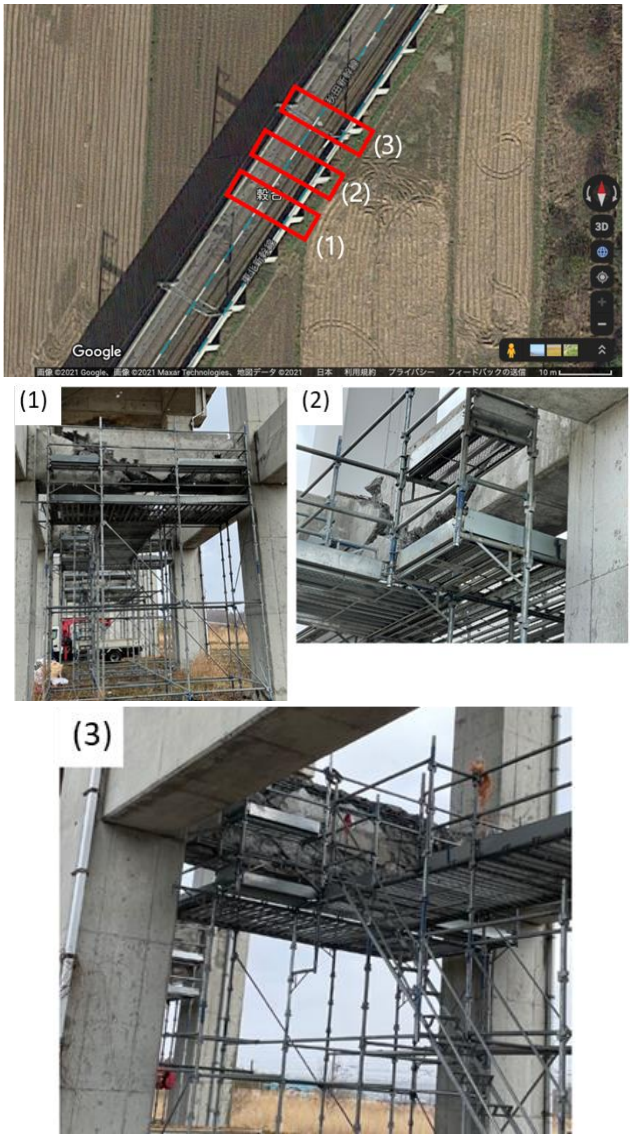

Photo 6 Damage of Shinkansen Viaduct.

5. DAMAGE TO BUILDINGS

(1) Koriyama City

Several high-rise buildings in Koriyama City suffered relatively severe damage. Photo7 shows a reinforced concrete (RC) office building. The glass of windows on the first floor of the building was broken. Walls between the windows on the second floor and above had severe shear damage, and X-shaped cracks were clearly visible. The building shown in Photo 8 is approximately 500 m west of the building in Photo 7, also an office building of RC structure. The building has cracks at the joints of the components and at the corners of the windows inside the facade, and the tiles on the surface have fallen off, but they do not affect normal use.

Photo 9 shows a hotel in the city. It is out of business due to the severe damage. Externally, an X-shaped shear crack can be seen on the wall between the windows. Photo 10 shows a library. It is out of service

due to severe damage. The damage is mainly concentrated at the entrance of the building. The concrete at the foot of the reinforced concrete column supporting the superstructure was crushed, and the reinforcement was exposed and seated. The large vibration of the entrance structure caused large damage to the wall connected to it.

Photo 11 shows a steel-reinforced concrete (SRC) residential building. The building was significantly damaged during the Great East Japan Earthquake in 2011[6], and its strength was increased after seismic repair[6]. However, a certain degree of damage was caused in this earthquake. As shown in the Photo, significant cracks were produced in the non-structural wall under the veranda on the north elevation.

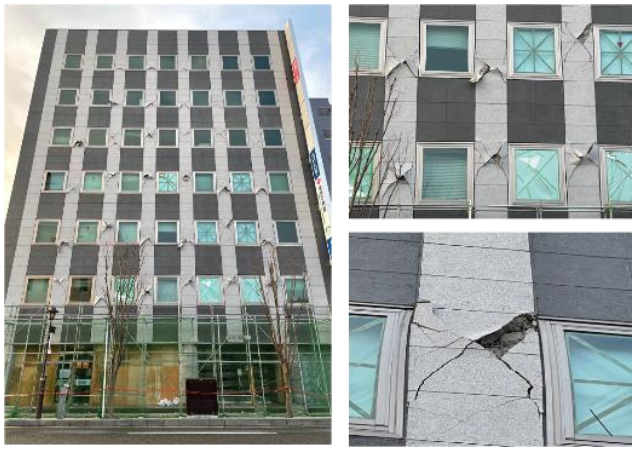

Photo 7 An office building in Koriyama City.
(north elevation, east-west direction)

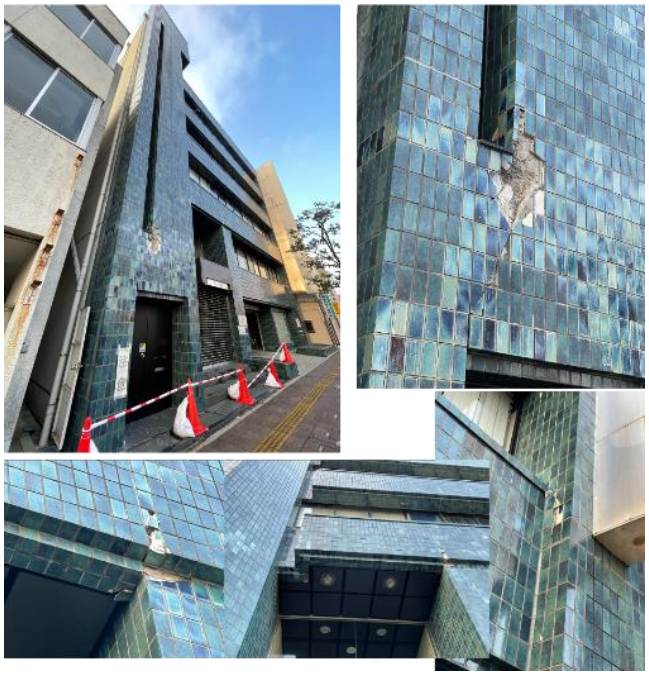

Photo 8 An office building in Koriyama City.
(north elevation, east-west direction)

Photo 9 A hotel in Koriyama City.
(west elevation, south-north direction)

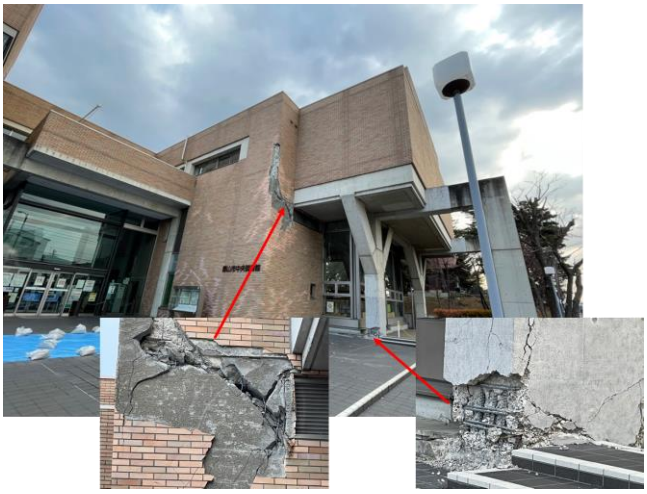

Photo 10 A library in Koriyama City.
(south elevation, east-west direction)

Photo 11 A residential building with SRC structure in Koriyama City. (north elevation, east-west direction)

Photo 12 A residential building with SRC structure in Fukushima City. (south elevation, east-west orientation)

Photo 13 Representative damage to house in Shinchi Town.

(2) Fukushima City

According to the field survey, there appeared to be minor damage to buildings in Fukushima City. 1The building shown in Photo 12 and the building in Photo 11 are both SRC residential buildings, and the damage was similar such as the wall between the windows produced obvious cracks and concrete spalling. Also, the corner column on the 1st floor had large deformation near the column head.

(3) Shinchi Town, Soma District

During the on-site survey we found that Shinchi Town,Soma District is a place with high concentration of housing damage. Photo 13 shows some of the representative photos of house damage. The two photos in the upper sec-tion show two RC buildings with cracks in the walls at the second story. The damage to the buildings in the middle and lower sections in this photo was in the form of typical damage, i.e., roof tiles peeling off. Also, as shown in Photo 14, the air conditioning system and the ceiling of the office building of Shinchi Town were dam-aged to some extent but did not affect normal use

Photo 14 Damage to the interior of office building of Shinchi Town.

Photo 15 Damage to Miyagi Hospital..

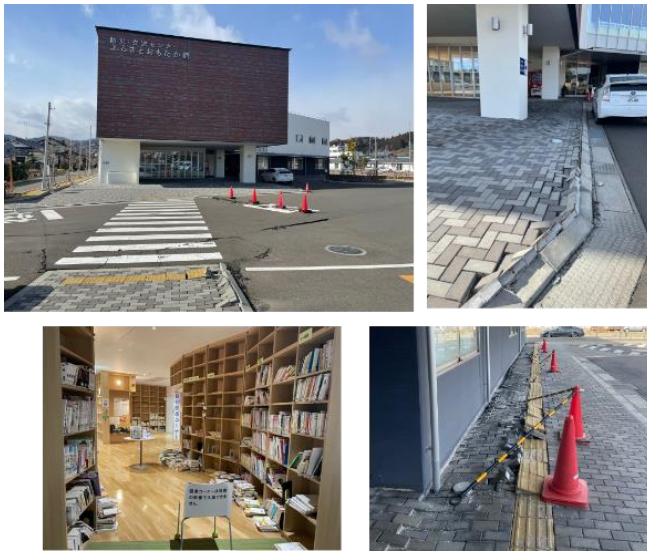

Photo 16 Damage to Disaster Prevention Communication Center in Yamamoto Town

(4) Yamamoto Town, Watari District

No extensive building damage was found near Yamamoto town at where the maximum acceleration of this earthquake was recorded. However, severe damage occurred to the buildings of Miyagi Hospital. As shown in Photo 15, the main part of the hospital building did not suffer significant damage. However, the branch building next to it was severely damaged, and the column feet were severely bent. Also, the water supply system of the hospital was damaged. In addition, as shown in Photo 16**,** the surrounding ground of the Disaster Prevention and Communication Center in Yamamoto Town was deformed. Though there was no damage to the building, the inside library was out of service due to severe scattering.

6. SUMMARY

Damage, such as road pavement cracks, cracks around the abutment, and suspected liquefaction in Soma Overpass Bridge and Soma East Bridge are reported. Cracks and spalling due to shear deformation in horizontal beams of the frame piers of the Shinkansen viaduct near Shiroishi Zao station were found. During this earthquake, the damage to buildings was not severe compared to the strong ground motions. However, we cannot ignore the fact that the short-period characteristics of strong ground motions in this earthquake had a relatively small impact on wooden houses. The site investigation revealed that there are still some problems that need to be identified and taken seriously.

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