Reconnaissance Report on Bridge Damage caused by the January 1st, 2024, Noto Peninsula Earthquake, Japan

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Key Facts

- Hazard Type: Earthquake
- Date of the disaster: January 1st, 2024
- Location of the survey: Anamizu City, Nanao City, Shika Town, Suzu City, Wajima City
- Date of the field survey: January 20th – 22nd, April 23rd - 25th, 2024
- Survey tools: Digital Camera, GPS
- Key findings: Damage to the piers was limited, with most of the bridge damage resulting from ground deformation behind the abutments. In some cases, settlement of the ground caused abutments to tilt, leading to damage to bearings at the bridge ends.

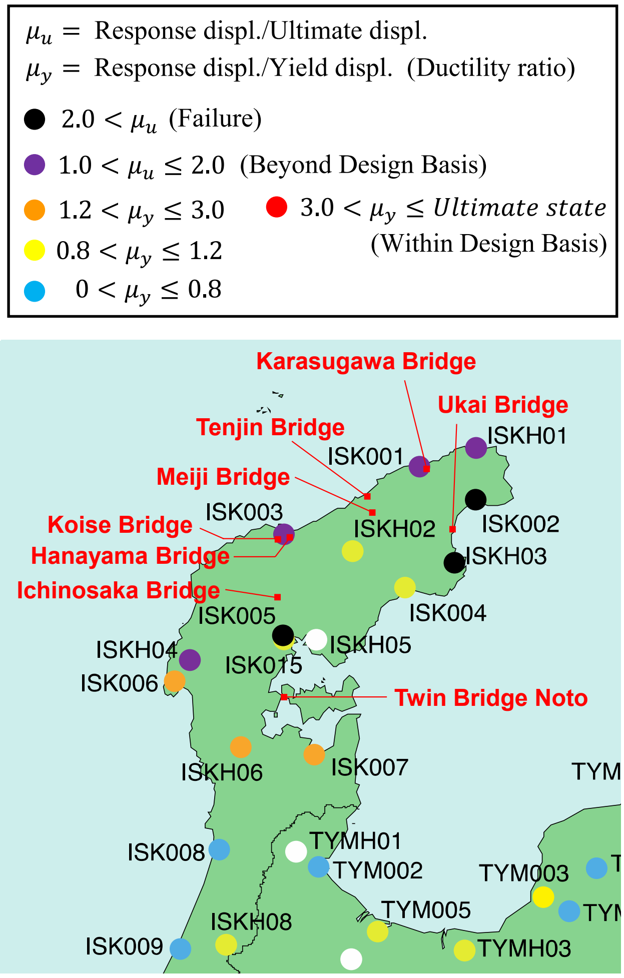
Key Words : *Noto Peninsula Earthquke, Damage to bridge, Pier, Abutment, Bearing*

1. INTRODUCTION

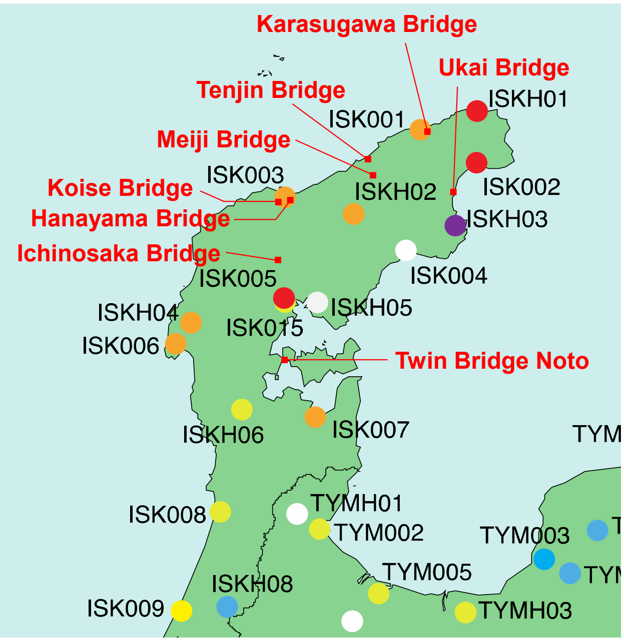
On January 1, 2024, at 16:10, a moment magnitude 7.5 earthquake occurred on the Noto Peninsula, referred to as the 2024 Noto Peninsula Earthquake. This earthquake caused severe ground and structural damage across a large area of the Noto peninsula. During the 2024 Noto Peninsula Earthquake, significant strong ground motions were reported[1)]. For example, the maximum ground acceleration of the horizontal component observed at K-NET ISK006 station reached 2.78 g. K-NET ISK002 and ISK005 recorded large peak ground velocities of 1.31 m/s and 1.59 m/s, respectively, along with significant spectral accelerations of 1.3 g and 2.2 g at T = 1.0 s. These values are similar to the damage-prone record in the 1995 Kobe earthquake (JR Takatori record). Thus, this report summarizes the bridge damage caused by the 2024 Noto Peninsula Earthquake.

2. GEOGRAPHIC LOCATION OF THE TARGET BRIDGE AND PRELIMINARY RESULTS OF THE NUMERICAL ANALYSIS

Takahashi[2)] conducted a three-dimensional nonlinear seismic response analysis using the observed seismic data from the 2024 Noto Peninsula Earthquake. This analysis utilized numerical models of road bridge piers, validated against full-scale RC road pier shaking table tests. The results demonstrated that the multiple earthquake ground motions observed in the 2024 Noto Peninsula Earthquake were strong enough to plasticize the bridge piers according to the 2002 Specifications for Highway Bridges (**Fig. 1**). Furthermore, it was shown that if the piers had not been seismically retrofitted after 1970, the damage to the piers could have been much greater, potentially leading to ultimate failure. Therefore, it is crucial to consider



(a) Estimation of seismic response of RC road bridge piers in the 1970s.



(b) Estimation of seismic response of RC road bridge piers in the 2000s.

Fig.1 Geographic location of target bridges and preliminary results of the numerical analysis by Takahashi[2)]

whether the observed damage to the bridge aligns with the design expectations, taking into account the strength of the earthquake motions observed nearby, rather than simply discussing whether the bridge was damaged or not. It is important to note that the seismic motions utilized in Takahashi's numerical analyses were not recorded at the exact location of the bridges, and Takahashi's numerical analysis results were specific to particular piers; hence, this report evaluates the observed damage to the bridges, compared with the results of Takahashi's numerical analyses.

3. SEISMIC DAMAGE TO BRIDGE PIERS

(1) Ichinosaka Bridge (Photo. 1)

Ichinosaka Bridge, located on the Nanao-Wajima Line of Prefectural Route 1, has a longitudinal length of 175.2 meters and a traverse width of 7.5 meters, which was put into service in 1980. The bridge piers are being retrofitted with steel plate jacketing. No damage has been observed in the seismically retrofitted sections, which aligns with the results of Takahashi's numerical analysis[2)]. However, concrete spalling damage occurred at the pier overhang's root. This is considered to be due to the structural weakness shifting from the pier base to the root of the overhang as a result of the steel plate jacketing.

(2) Twin Bridge Noto (Photo. 2)

Twin Bridge Noto is a long bridge that began service in 1999, connecting the Noto island and the Noto

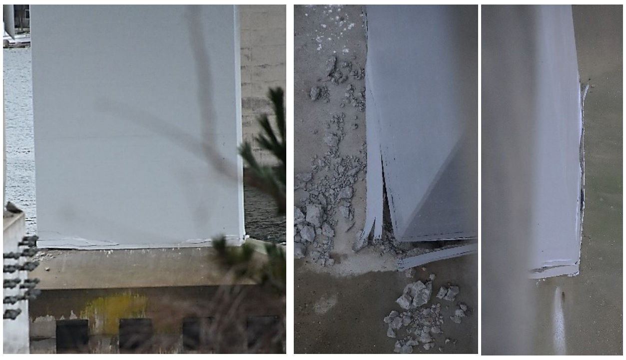
(a) Overall view

(b) Damage with concrete spalling at the root of the pier overhang

Photo. 1 Damage to bridge piers of Ichinosaka Bridge (37°17'41.9"N, 136°53'43.1"E)

(a) Overall view

(c) Failure of girder at bearing portion



(b) Damage with carbon fiber rupture at the base of pier

Photo. 2 Damage to Twin Bridge Noto (37°08'09.9"N, 136°54'23.5"E)

Peninsula in Nanao City. The bridge has a longitudinal length of 620 meters, with the Noto island side featuring a continuous box girder bridge with two PC spans, while the Noto Peninsula side comprises a continuous cable-stayed bridge with three PC spans. At Twin Bridge Noto, carbon fiber rupture occurred at the base of the columns in the piers retrofitted with carbon fiber jacketing. It is noteworthy that deformation exceeding the ultimate displacement likely occurred despite the seismic retrofitting.

Additionally, a collision between the abutment and the bridge girder on the Noto island side caused the girder to fail at the bearing portion. Bearing failure also occurred at the opposite end of the girder.

(3) Karasugawa Bridge (Photo. 3)

The Karasugawa Bridge, located on National Route 249 to the northern part of Suzu City, has a longitudinal length of 210 meters and a traverse width of 9.5 meters. It was put into service in 2011. Structural failures at the base of the piers have been observed, including spalling of concrete and exposure of rebar. The damage state of the Karasugawa Bridge's piers is consistent with numerical results, as seismic motions capable of generating responses with ductility ratios of 1.2 to 3.0 for RC road bridge piers in the 2000s were observed in the geographic location of the Karasugawa Bridge.

Additionally, ground failure behind the abutments was observed, causing the abutments to move forward and resulting in significant deformation of the bearings. Consequently, the failure of the attachments of the rubber bearings was observed.

(a) Overall view

(b) Damage with spalling of concrete and exposure of rebar at the base of pier

(c) Ground failure behind abutment

(d) Failure of attachments of rubber bearings

Photo. 3 Damage to Karasugawa Bridge (37°29'55.7"N, 137°11'00.3"E)

4. STRUCTURAL DAMAGE TO BRIDGES EXCLUDING PIERS

(1) Ukai Bridge (Photo. 4)

Ukai Bridge, located south of Suzu City and crossing the Ukai River, has a length of 54 meters and a width of 8.5 meters. It has been in service since 1960. The 2024 Noto Peninsula earthquake caused a collapse of the section designated for pedestrian traffic. Additionally, large cracks appeared on the road surface, and there was lateral displacement of the girders in the vehicular traffic section. Ground settlement behind the abutments caused steps to form in the approaches to the bridge. No significant damage to the piers was observed.

(2) Koise Bridge (Photo. 5)

Koise Bridge, which crosses the Fugeshi River in Wajima City, has a longitudinal length of 14 meters and a traverse width of 4.5 meters. It was put into service in 1999. At the approach to Koise Bridge, steps at the approach parts to the bridge were observed due to the settlement of the ground behind the abutments. Additionally, damage to the bottom mounting and displacement stoppers of the rubber bearings was observed at the bridge girder ends.

(3) Hanayama Bridge (Photo. 6)

Hanayama Bridge, located in Wajima City, has a longitudinal length of 52.8 meters and a traverse width of 7.3 meters and was put into service in 2002. Due to the deformation of the surrounding ground, the bridge's abutment tilted significantly, causing damage to the rubber bearings at the ends of the bridge. Specifically, the mounting of the east side rubber bearing failed, and the west side rubber bearing ruptured.

(a) Collapse of the section designated for pedestrian traffic

(b) Lateral displacement of vehicular traffic section (c) Step at approaches to bridge

Photo. 4 Damage to Ukai Bridge (37°23'60.0"N, 137°14'24.0"E)

(a) Overall view (b) Step at approaches to bridge

(c) Damage to attachment of rubber bearings

Photo. 5 Damage to Koise Bridge (37°23'08.1"N, 136°53'24.1"E)

(4) Meiji Bridge (Photo. 7)

Meiji Bridge, crossing the Machino River in the eastern part of Wajima city, has a longitudinal length of 46 meters and a traverse width of 6.5 meters and has been in service since 1986. Significant ground deformation occurred in the vicinity of the Meiji Bridge, causing the abutments to tilt and creating a step at the approaches to the bridge. Additionally, a collision between the abutment and the bridge girder resulted in damage to the abutment, including concrete spalling and exposed rebar.

(5) Tenjin Bridge (Photo. 8)

Tenjin Bridge, located near the mouth of the Macnino River in the eastern part of Wajima city, has a longitudinal length of 60 meters and a traverse width

(a) Overall view

(b) Tilting of bridge abutments

(c) Damage to rubber bearings

Photo. 6 Damage to Hanayama Bridge (37°23'10.0"N, 136°55'05.0"E)

(a) Overall view

(b) Ground deformation occurred in vicinity of bridge

(c) Tilting of bridge abutment

(d) Damage to bridge abutment

Photo. 7 Damage to Meiji Bridge (37°23'37.6"N, 137°04'54.4"E)

(a) Overall view

(b) Revetment deformation occurred in vicinity of bridge

(c) Step at approaches to bridge

(d) Rupture of rubber bearing

Photo. 8 Damage to Tenjin Bridge (37°26'57.1"N, 137°04'13.7"E)

of 17.3 meters. It was put into service in 2000. Significant ground deformation occurred near the Meiji Bridge, resulting in steps forming at the approach to the Tenjin Bridge. Additionally, the rubber bearings at the ends of the girders ruptured. However, no damage occurred to the piers.

5. SUMMARY

In the 2024 Noto Peninsula earthquake, the Karasugawa Bridge was observed to have failed, exhibiting concrete spalling and exposed rebars at the pier bases. The failure state was consistent with the results of Takahashi's numerical analysis. There were piers where structural weaknesses shifted due to seismic retrofitting, resulting in failures at portions that were not retrofitted (Ichinosaka Bridge). Additionally, there were piers where carbon fiber ruptured at the column base (Twin Bridge Noto). Furthermore, multiple bridges experienced tilting of abutments and damage to bearings at the bridge ends.

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