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TSUNAMI DAMAGE TO BRIDGE STRUCTURES IN RIKUZEN-TAKADA CITY AND THE EMERGENCY ROAD NETWORK RECOVERY ACTIONS

Shigeki UNJOH[1]

[1] Research Coordinator for Earthquake Disaster Prevention, National Institute for Land and Infrastructure Management, MLIT, Tsukuba, Japan, unjoh-s92ta@nilim.go.jp

ABSTRACT: The 2011 Great East Japan Earthquake caused extensive damage due to the strong shaking and the destructive tsunami. In particular, the huge tsunami attacked the coast region of Tohoku to Kanto area and caused heavy damage to the roads and bridges. MLIT conducted urgent recovery actions just after the event to secure the emergency transportation routes to connect affected areas. This paper presents the tsunami damage to roads and bridge structures in a city in Iwate prefecture and the discussions of the emergency road network recovery methods.

Key Words: Great East Japan earthquake, tsunami, bridge damage, emergency road network recovery

INTRODUCTION

The 2011 Great East Japan Earthquake caused extensive damage due to the strong shaking and the destructive tsunami. In particular, the huge tsunami attacked the coast region of Tohoku to Kanto area and everything in the region including building, houses and infrastructures was washed out by the tsunami. Several bridges were completely washed out as well and the areas were disrupted along the rivers due to the damage.

The road networks are one of the most critical infrastructures when a natural disaster occurs. Since the roads play an important role for the evacuation of affected people and the transportation of emergency goods and materials, the road network function is necessary to be maintained or to be recovered as soon as possible even just after a heavy natural disaster.

The author was dispatched to investigate the road and bridge damage on the national highway route 45 in a section of Rikuzen-Takada city just after the 2011 Great East Japan Earthquake. Rikuzen-Takada city is located at the Pacific coast area in the south of Iwate prefecture, and almost at the boundary with Miyagi prefecture. The city was heavily damaged by the destructive tsunami with the height of over 10m. 1,728 people were killed or missing, which corresponds to about 7% of total city population at that time, and about 3,000 houses were completely collapsed. National highway route 45 was along the coast line and 4 sections were completely disrupted by the damage of bridges.

The damaged and survived roads and bridges were carefully investigated and the quick recovery works were conducted by MLIT.

This paper presents the tsunami damage to roads and bridge structures and the discussions of the emergency road network recovery methods. The damage of roads and bridges in Rikuzen-Takada city is discussed as one of the critical damage experiences.

DAMAGE OF ROADS AND BRIDGES ON NATIONAL HIGHWAY ROUTE 45

The national highway route 45 connects Sendai City with Aomori City along the Pacific "Sanriku" coast of Miyagi, Iwate and Aomori prefectures. During the 2011 Great East Japan Earthquake, road function of 22 locations was disrupted and 5 bridges were washed out caused by the destructive tsunami. Fig.1 shows the highway network in the Pacific side of Miyagi and Iwate prefectures and the damaged section of the national highway route 45 (Tohoku Bureau of MLIT, 2011a). Typical heavy damage to bridges was the wash-out of superstructures as shown in Photo 1. The strong tsunami failed bearing supports and washed out the superstructures. On the other hand, the most of substructures of the bridges, in which the superstructures were washed out, survived with only minor damage.

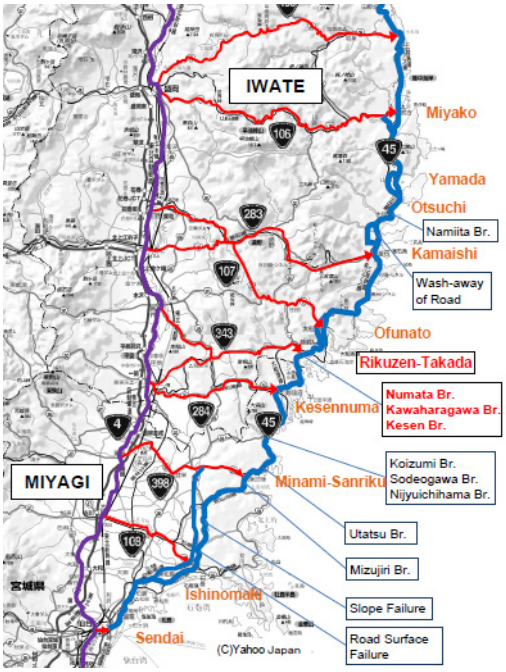

Fig.1 Damage on National Highway Route 45 (Tohoku Bureau of MLIT, 2011a)

Photo 1 Typical Heavy Damage of Bridges: Wash-out of Superstructures by Tsunami

One of the most urgent issues for the rehabilitation of the affected Sanriku coastal areas was to open the emergency transportation network in order to secure the evacuation and the transport of emergency goods and supplies. Just after the earthquake, the Tohoku Bureau of MLIT decided to conduct the “Comb-Operation” to open and secure the whole emergency routes to connect the affected areas (Tohoku Bureau of MLIT, 2011b). The operation consisted of 3 steps as:

Step 1) Secure national highway route 4 (trunk route in Tohoku network) that runs in North-South direction

Step 2) Secure East-West national highway routes that connect horizontally between national highway route 4 and the Sanriku areas

Step 3) Open and repair the damaged sections of national highway route 45

Based on the report from the Tohoku Bureau of MILT, Step 1) was completed within one day and 11 routes out of 16 were completed by March 12 in Step 2). MLIT issued on March 18, just one week after the earthquake, that the emergency Comb-operation completed on the day and that 15 routes out of 16 that connected between national highway route 4 and affected areas within four days, and that 97 % of national highway route 45 was completed to open to traffic. It was evaluated as a quick and successful recovery work. MLIT explained that the reason of such successful actions was made by (Tohoku Bureau of MLIT, 2011c):

1) Effective seismic retrofit for bridges, resulted in a small amount damage of bridges due to the strong shaking
2) Effective “Comb-Operation” to open highway networks
3) Effective preparation on the contract agreement and the close cooperation between government and private sectors for the emergency disaster management

DAMAGE OF ROADS AND BRIDGES IN RIKUZEN-TAKADA CITY

Damage of Rikuzen-Takada City caused by Tsunami

Photo 2 shows the evidences of the attacked tsunami height left at the buildings and the signboard along the coast area in Rikuzen-Takada city. The height was estimated as around 10m from the ground level. Everything was destroyed and washed out, and almost nothing except large buildings was left in the coastal area. On the other hand, a massive amount of debris was swept and left on the landward side apart from the coast line, and the roads was completely closed by that. Photo 3 shows a large amount of debris and the urgently opened roads.

Photo 2 Tsunami Height in Rikuzen-Takada City: Around 10m

Photo 3 A Massive Amount of Debris on Roads and Urgently Opened Road

Damage of National Highway Route 45 in Rikuzen-Takada City

Overview

National highway route 45 was along the coast line and 4 sections were completely disrupted by the damage of bridges. In the Rikuzen-Takada city, there were 4 bridges and 2 culverts on national highway route 45 and 6 bridges on local highways. Photo 4 shows the aerial photo of Rikuzen-Takada city, in which red circles and red dotted lines show the locations of 12 bridges and the affected area by tsunami, respectively. Three bridges out of 12 were heavily damaged by the tsunami, which were on national highway route 45 as shown in Fig. 2. Superstructures of two bridges were completely washed out and the backfill soils of the abutments were heavily scoured. The details of damage and the repair of the bridges will be discussed later. Furthermore, the peeling-off of road pavement and the scouring of soil sections due to the tsunami were also observed at several locations as shown in Photo 5.

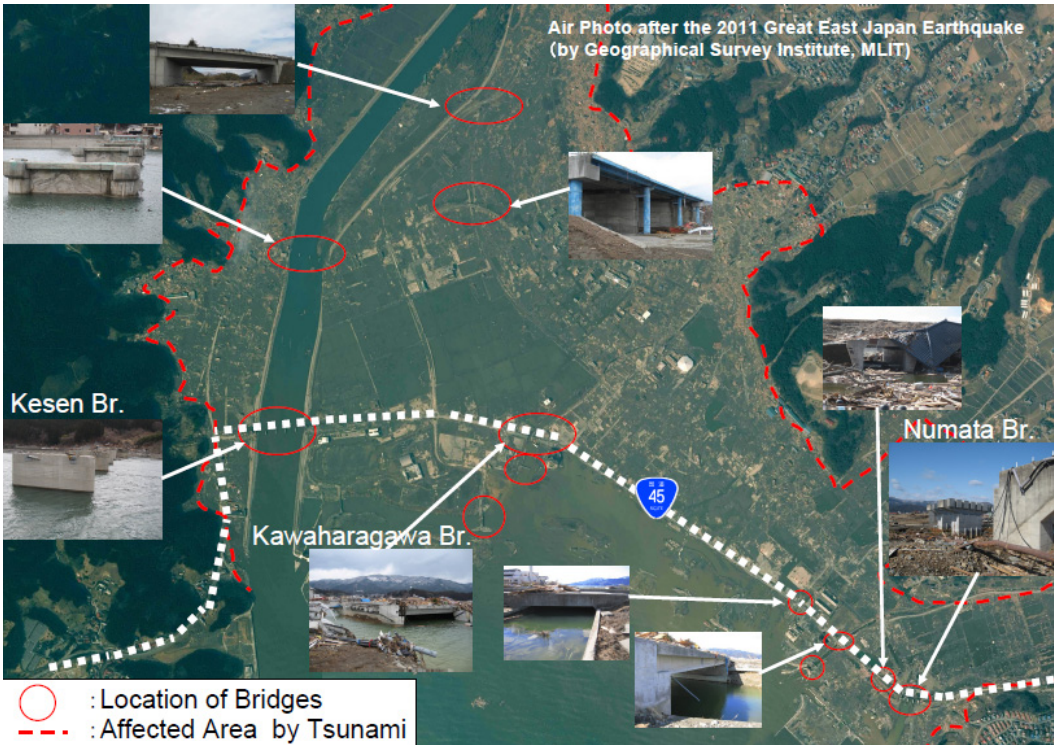

Photo 4 Rikuzen-Takada City and Inundated Area by Tsunami

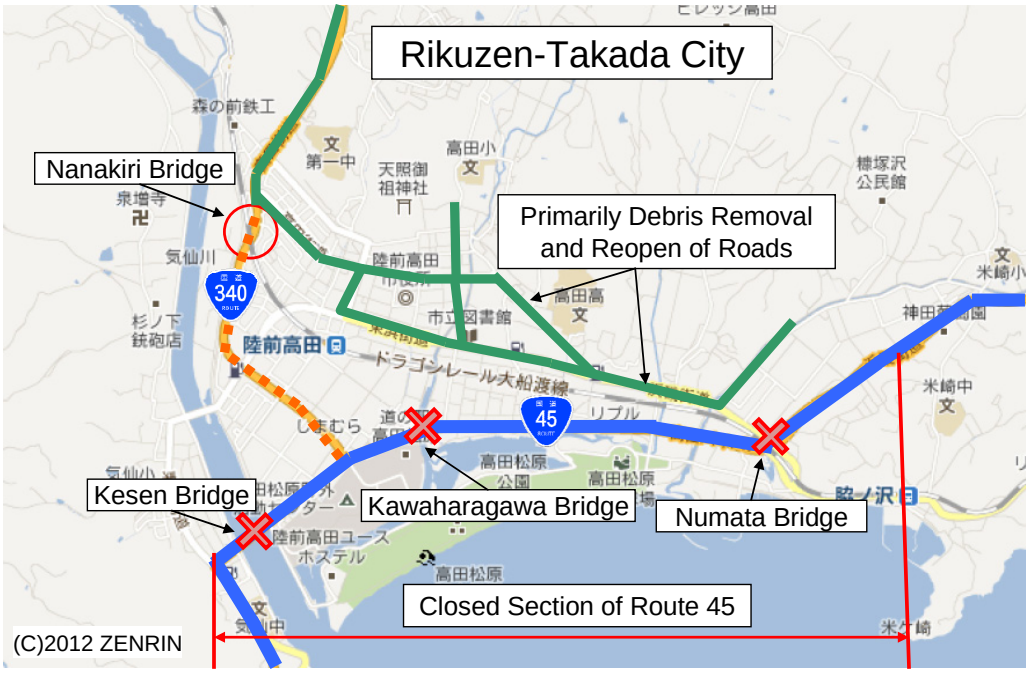

Fig. 2 Map of Rikuzen-Takada City and the Damaged Bridge Section

Photo 5 Peeling-off of Road Pavement and Scouring of Soil Sections

Kesen Bridge

Kesen Bridge, which crossed Kesen river, consisted of 108.5m long 3-span continuous steel girder and 72.5 m long 2-span continuous steel girder bridges. The total bridge length was 181.5 m. The bridge was constructed in 1982. The substructures were reinforced concrete wall-type piers that were supported by steel pile foundations. It should be noted here that the original bearings were steel bearings but replaced by rubber type bearings for the seismic retrofit objective before the 2011 earthquake. Viscous dampers were also installed between superstructures and substructures to reduce the earthquake displacement response.

Photo 6 shows the Kesen bridge before the 2011 earthquake and the damaged by tsunami. Steel girders were washed out toward the upstream side as shown in Photo 7. The wash-out distance was estimated as 400m from the original location. The concrete slab and steel girders were completely separated and the steel girders were heavily deformed as U-shaped or V-shaped. The rubber bearings were broken at the rubber layers, and the damper rods or the set bolts of all the viscous dampers were fractured. Backfill soil at one of the abutments was also heavily scoured as shown in Photo 8.

Photo 6 Damage of Kesen Bridge (1)
(Left: Original Bridge before the 2011 Earthquake, Right: Wash-out of Superstructures)

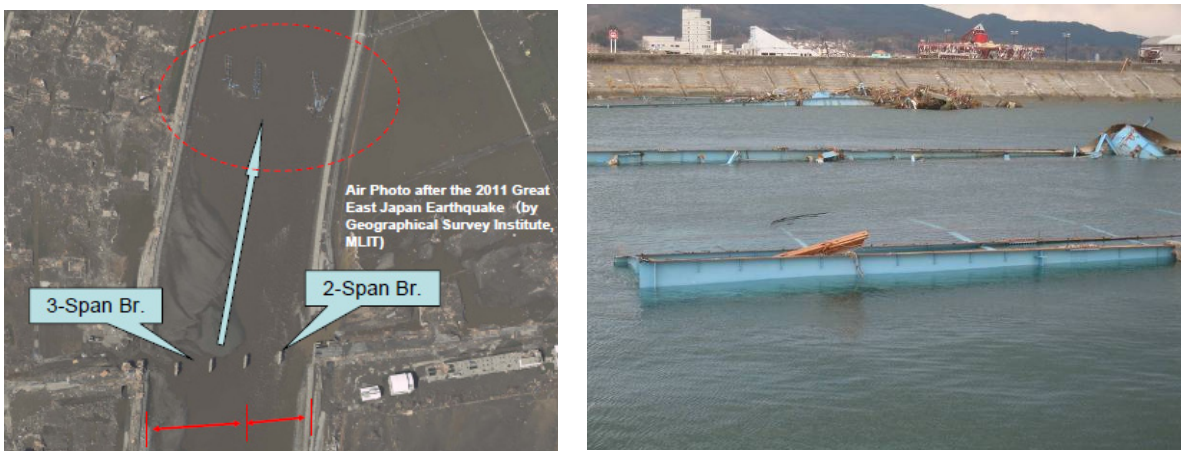

Photo 7 Damage of Kesen Bridge (2)
(Left: Distance of Washed-out Superstructure, Right: Deformed Steel Girders)

Photo 8 Scouring of Abutment Backfill of Kesen Bridge

Kawaharagawa Bridge

Kawaharagawa bridge was a simply-supported PC slab bridge, which was constructed in 2003. Bridge length was 28.8 m. Abutments were supported by cast-in-place RC pile foundations. The river bottom was around 6m from the bridge girder and the piles of abutments were placed up to 29.5m deep and

supported by stiff soils at the pile toes.

The backfill soil of one abutment was heavily washed out over about 20m long as shown in Photo 9. The bridge did not suffer any significant damage. Any remarkable displacement was not found at the concrete girders, and the unseating devises by PC cables which connected superstructure and abutment parapet walls were still effective. The possibility of scouring effect was estimated to occur around the abutment foundations but the vertical stability was estimated to be enough because the concrete piles were used.

Photo 9 Wash-out of Backfill Soil of Kawaharagawa Bridge

Numata Bridge

Numata bridge consisted of 3-span simply-supported PC T-girders, which was constructed in 1983. Total bridge length was 65.24 m. The bridge passed over the Ofunato railway. The substructures were reinforced concrete wall type piers supported by cast-in-place concrete pile foundations. It should be noted here that the bridge was seismically retrofitted by concrete jacketing for piers and by installing the concrete block type unseating prevention devices before the 2011 earthquake.

Three spans were washed out to the mountain side just beside the bridge as shown in Photo 10. Back fill soil of both abutments were heavily scoured and lost as shown in Photo 11.

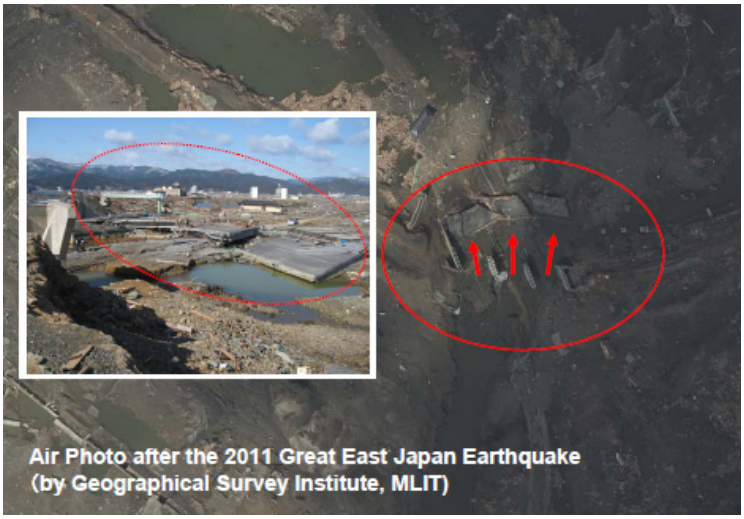

Photo 10 Damage of Numata Bridge (1): Wash-out of 3 Spans

Photo 11 Damage of Numata Bridge
(Left: Survived Piers, Right: Heavy Scouring of Backfill Soil at Abutment)

Emergency Recovery Investigations and Discussions

The recovery works from the tsunami damage were urgently conducted in Rikuzen-Takada city. As shown in Fig. 4, the urgent removal of the debris and opening of the roads were made. To open the national highway route 45, it was necessary to carry the heavy equipments for the recovery constructions. The national highway route 340 was also investigated in order to evaluate whether the route could be used or not for that objective. The critical section was the Nanakiri bridge which passed over the Ofunato railway.

Nanakiri bridge is a simply-supported PC T-girder bridge with length of 36.5m as shown in Photo 12. The bridge was constructed in 1998. The slight scouring was found around both sides of abutment and the bridge railings were completely deformed toward the mountain side, but the bridge itself was evaluated as almost no damage and usable for the emergency route. Then the recovery works of the national highway route 45 was made using national highway route 340 as well as from the east side.

The repair method for the Kesen bridge, in which the superstructures were completely washed out, was discussed in order to quickly recover the road function. The possible methods were: 1) to construct temporary girders on the existing piers, 2) to construct temporary bridge beside the damaged bridge. Finally, considering the stability of survived piers and the final permanent construction in near future, MLIT decided to select the method 2) and completed in June 10 as shown in Photo 13. The final rehabilitation method of the bridge will be determined based on the final recovery planning of the Rikuzen-Takada city.

Photo 12 Investigation of Nanakiri Bridge
(Left: Side View, Right: Slight Scouring of Backfill Soil at Abutment)

Photo 13 Construction of Temporary Bridge at Kesen Bridge

The repair method for the Kawaharagawa bridge, in which the abutment backfill was heavily washed out over 20 m, was discussed in order to quickly recover the road function. The possible methods were: 1) to construct temporary girders on the existing bridge to pass over the wash-out section, 2) to fill soils into the wash-out section. The investigation and discussion were made on the stability of the existing abutment to support the temporary girders. Finally, considering the process from the temporary to permanent repairs of the scoured abutment, MLIT decided to select the method 1) and completed on March 25 as shown in Photo 14. Then the backfill soil was filled at the wash-out sections finally.

Photo 14 Emergency Recovery for Kawaharagawa Bridge
(Left: Construction of Temporary Girders (Tohoku Bureau of MLIT, 2011c),
Right: Refilled Backfill of Scoured Abutment)

The repair method for the Numata bridge, in which 3 span were washed out and the backfill soils at abutments were heavily scoured, was discussed in order to quickly recover the road function. The Ofunato railway under the bridge was destructively damaged all along the line and the railway operation stopped because of the emergency treatment. Therefore, the temporary road was constructed just beside the bridge, instead of repairing the Numata bridge itself by using temporary bridges, and opened on March 25. The final rehabilitation method of the bridge will be determined based on the final recovery planning of the Rikuzen-Takada city and the Ofunato railway.

Photo 11 Construction of Temporary Road beside Numata Bridge (Tohoku Bureau of MLIT, 2011c)

CONCLUSIONS

This paper presented the tsunami damage to roads and bridge structures and the discussion of the emergency road network recovery methods. The damage of roads and bridges in the Rikuzen-Takada city was discussed as one of the critical damage experiences. Such urgent recovery works were made at all of the damaged sections.

It is recognized again that the road network is extremely important in particular during and after the disasters. Therefore, once the damage occurs and the road function is lost, it is essential to recover the function as soon as possible for the evacuation and the transport of the emergency goods. The quick and precise evaluation technology of the structural damage and soundness as well as the quick recovery technology of the road function are still critically important and the further study is necessary based on the lessons learned from the 2011 earthquake.

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