Verification of Disaster Process in the Bridge Exposed to a Large-scale Flood and Study of Disaster Reduction Measures based on Verification Results

(Study period: FY2016 to FY2017)

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keywords: bridge damage, disaster reduction measures

1. Characteristics of damage caused by 2016 Typhoon No. 10, etc.

Heavy rain by the 2016 Typhoon No. 10 etc., caused damage to many river bridges in Hokkaido and Iwate Prefecture. The forms of damage found in these disasters include damage caused by inundation of flood flow over bridges or approach embankment and damage caused to abutments due to expansion of bank erosion not accompanying flood. If bridge body (beam, pier, abutment) is damaged, traffic network in stricken area is interrupted for a long time and recovery takes much time, which may cause a mid- and long-term impact on stricken area. There was also a case where a car fell when traveling on the road collapsed by flood in Hokkaido. Thus, necessity for stopping traffic on the bridge in case of a flood and timing of determination are also mentioned as issues to address.

Since the scale of rainfall has been increasing due to the effect of climate changes, it is urgently required to study how to prepare countermeasures for a large number of bridges with limited budget, including disaster reduction measures for avoiding critical damage to bridge body and non-structural measures for ensuring the safety of bridge users.

This study examined the process of damage to abutments with a movable bed model experiment for the forms of damage to abutments by river erosion, on which few studies were conducted for the bridges damaged by the 2016 heavy rain in Hokkaido and Iwate.

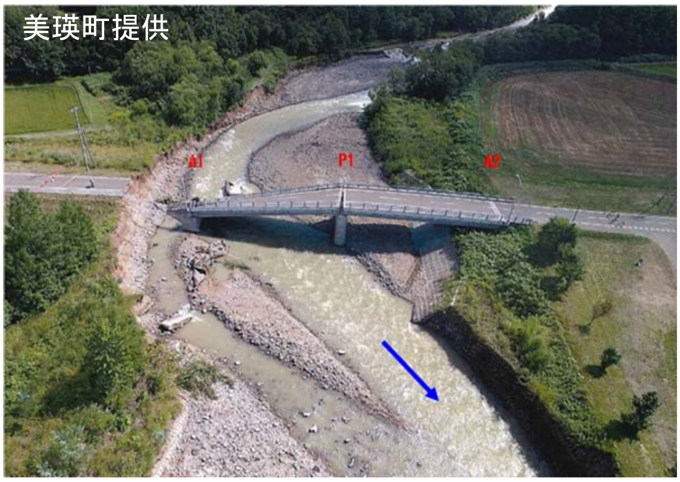

Fig. 1 Damage to Kyusen Bridge (Bebetsu River, Hokkaido)

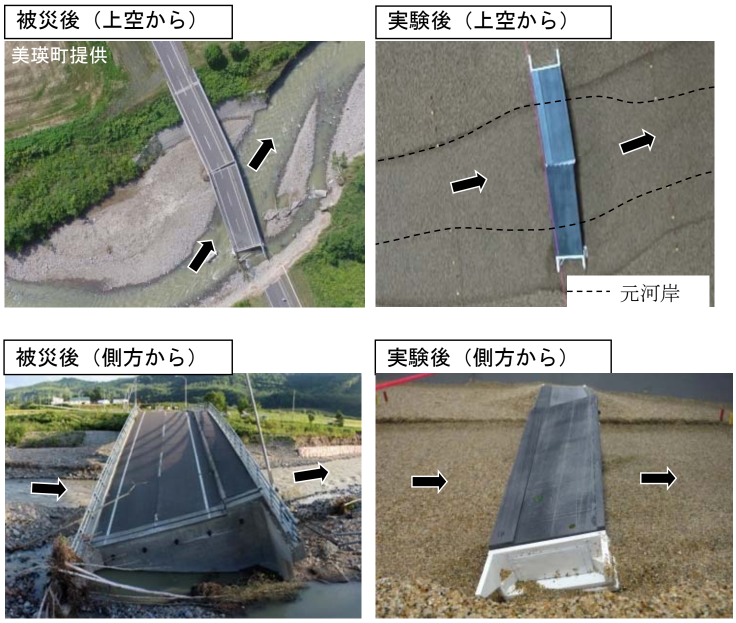

Fig. 2 Comparison of model experiment and site damage

2. Movable bed model experiment for grasping the basic damage mechanism of abutment accompanying bank erosion

As a result of the model experiment, when bank erosion from the abutment upstream proceeded near the abutment, back fills of the abutment were lost and the abutment sank eventually (Fig. 2). It was confirmed that the bed height near the abutment changed in the following three conditions according to the elapse of time due to erosion / scour leading to abutment displacement and that the height decreased in each state (Fig. 3).

Condition 1: When bank erosion reached near the abutment, the height fell to the low water channel bed height.
Condition 2: Part and front face of the abutment were exposed by erosion, and local scour proceeded.
Condition 3: Bed height was lower than the height of abutment foundation and the abutment sank and inclined.

In addition, it was confirmed in the eroding process that when the bed height near the abutment is lower than the height of abutment foundation, back fills of the abutment are sucked out of the lower part of the abutment foundation in the channel direction and cavity is formed in the back fills (Fig. 3). This suggests necessity to stop traffic on the bridge quickly since damage may be proceeding in the channel even if the abutment seems sound in case of a flood.

3. Countermeasure based on the findings of the experiment

Based on the results of the model experiment, the following disaster reduction measures are for example mentioned for bridges that may be exposed to a large-scale flood and suffer damage due to progress of bank erosion.

- Develop revetment that prevents progress of bank erosion near the abutment in order to prevent progress to Condition 1,
- If bridge renewal is possible, develop the foot protection works or consider the depth of embedment corresponding to scour when the abutment is partially or its front face is exposed and then develop the abutment in order to prevent progress to Condition 2,
- If renewal of the existing bridge is difficult and there is a concern about progress to Condition 2 or further, install sensors for detecting the fall of bed height around the abutment and inclination of the abutment and stop traffic on the bridge with an automatic crossing gate when abnormality is detected, (Response to Condition 3)

4. Future activities

In cooperation with Road Structures Department, we are going to accumulate findings of the experiment and organize systematically disaster reduction measures for the bridge body in addition to abutment by analyzing bridge disaster cases confirmed in the past.

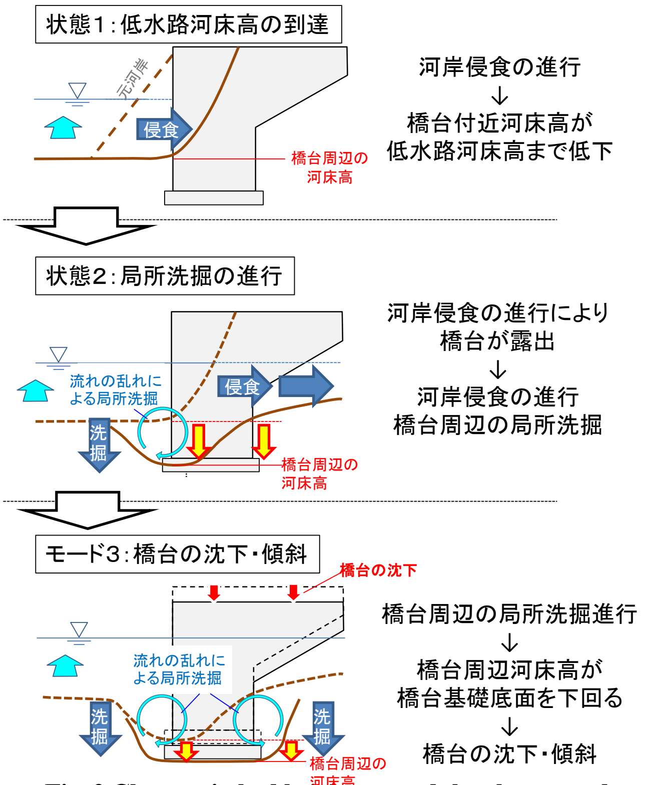

Fig. 3 Changes in bed height around the abutment due to progress of bank erosion

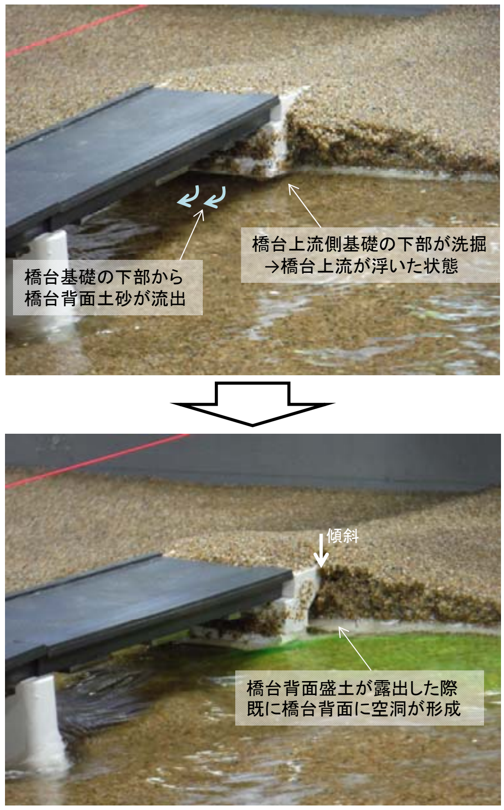

Fig. 4 Cavitation of the abutment back by sucking from under the abutment