Abstract

Title A Study on Anti-Tsunami Measures for Bridges

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[Abstract] (1,000words, 10points, single space)

The giant tsunami caused by the Great East Japan Earthquake in 2011 inflicted extensive damage in the Pacific coastal area around the Tohoku region. The tsunami washed away buildings and constructions in the coastal area. Bridge superstructures were also washed away. Since bridges are constructed at important points of road networks, traffic blocks due to washouts directly led to delays in lifesaving measures, emergency transportation, restoration, and recovery efforts. Accordingly, it is necessary to ensure the safety of bridges against tsunamis from the perspective of disaster prevention. Until now, no specific design methods or measures to counter the force of tsunamis have been established for bridges. Since the occurrence of major earthquakes is being predicted, it is desirable that bridge design methods and anti-tsunami measures be established immediately.

In this study, verification by experiments was conducted for the purpose of obtaining basic data to clarify mechanisms of bridge washouts and to reduce the force of tsunamis on bridges. Such basic data is necessary to consider bridge designs and anti-tsunami measures. The objects of the experiments were Kesen Bridge and Utatsu Bridge. Experiments were conducted using detailed bridge models, which reproduce the actual forms of the bridges, in order to clarify the washout mechanisms of bridges. Experiments were also conducted using a model with fairings—which were installed to reduce the horizontal force of tsunamis—to verify their effects.

In Chapter 2, knowledge concerning earthquakes and tsunamis was sorted out and the damage situation was analyzed using the results of bridge inspections. According to the results of the emergency inspections of the bridges within the jurisdiction of Tohoku Regional Development Bureau (Iwate Prefecture, Miyagi Prefecture and Fukushima Prefecture), 10% of the inspected bridges were affected by the tsunami and 93% of the bridges that were affected by the tsunami had damage. It means that most bridges affected by the tsunami were damaged. In addition, damage affecting load-bearing capacity was found in 3% of the bridges that had not been affected by the tsunami, whereas damage affecting load-bearing capacity was found in 14% of the bridges that had been affected by the tsunami. The results above show that serious damage tends to be inflicted if a bridge was affected by a tsunami.

In Chapter 3, detailed models were constructed reproducing the detailed configurations of Kesen Bridge and Utatsu Bridge, which were washed away. Forces acting on the models were examined through experiments and the washout mechanisms were clarified paying attention to the resilience of bearings.

Attention was paid to bearings to clarify the washout mechanism. It was suggested that a sear failure of a mounting bolt due to horizontal force triggered the Kesen Bridge to be washed away. According to a sequence of photographs taken at the time of the disaster, the bridge was washed away presumably by a tsunami similar to a steady flow. The steady flow rates that can wash away the bridge were calculated and it was presumed that a steady tsunami flow of 8.5 m/s or

above swept away Kesen Bridge.
Utatsu Bridge consists of a pre-tension PC simple T girder bridge (Span6) and a post-tension PC simple T girder bridge (Span9).
Based on the experimental results concerning Span6, the bridge was presumably washed away as the RC projection was destroyed by the tsunami's horizontal acting force. As in the case of Kesen Bridge, a video record at the time of the disaster showed that Utatsu Bridge was washed away by a tsunami closely resembling a steady flow, too. Based on calculating a steady flow that can demolish a bridge, a steady tsunami with a flow rate of 6.7 m/s or above destroyed the RC projection and washed away the bridge.
As for Span9, it was presumed that the washout started as the bearing side block was destroyed by the tsunami's horizontal acting force. At the same time as the bearing side block was destroyed by horizontal force, the lifting prevention device attached to the side block got out of place and then the bridge was washed away while rotating. As in the case of Span6, the flow rate of a steady flow that can destroy the structure was calculated and it was estimated that a steady tsunami with a flow rate of 6.9 m/s or above destroyed the side block and washed away the bridge.
It was confirmed that the main factor of the washouts was horizontal force caused by the tsunami. Therefore, it was understood that reducing the horizontal force is important when taking anti-tsunami measures for bridges.
In Chapter 4, experiments were conducted using a model with a fairing—effective for improving stability against wind—in order to reduce horizontal force, which is the main factor of washouts. Furthermore, experiments were conducted in which a slit was made in the fairing to suppress vertical upward force.
The experiment results confirmed that horizontal force by a tsunami can be reduced by installing a fairing. It was confirmed that a fairing is an effective measure to reduce horizontal force on bridges. Although a box-shaped fairing can reduce horizontal force more effectively than an L-shaped fairing, a box-shaped fairing increases vertical upward force.
It was confirmed that vertical upward force can be reduced if a slit is made in a box-shaped fairing. However, if a slit was made in a box-shaped fairing, its effect of reducing horizontal force was reduced to be around the same level as an L-shaped fairing with a slit. Therefore, it is reasonable to consider the balance between horizontal force and vertical upward force to select the type of fairings.
In this study, waves like hydraulic bores were produced by a gate-type wave generating device. However, actual tsunamis consist of various kinds of waves that differ from the experiments. On the other hand, there are anti-tsunami measures other than introducing fairings, such as reducing the girders' height or the overhang length of the floor slabs. The study on anti-tsunami measures for bridge superstructures is still in the developmental stage and further research is necessary.

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