Development of Methods for Determining Disaster Potential and Preventive Measures for Bridge Washouts and Scouring

(Research period: FY2019–FY2020)

Bridges and Structures Division, Road Structures Department
Head (Ph.D.Engineering) SHIRATO Masahiro Senior Researcher OKADATakao
Senior Researcher SASADA Yukihisa Researcher IHARA Takehiro

(Keywords) road bridges, bridge foundation scouring, bridge superstructure washouts

1. Introduction

In recent years, many road bridges have suffered damage due to torrential rains. For example, a bridge was closed to traffic for a long time due to scouring of its foundations in Typhoon Hagibis in 2019, and road bridges over the Kuma River suffered washout damage in several locations from the torrential rain in July 2020. To ensure that road continue to function during disasters, it is necessary to gain information on road bridges most at risk of scouring and washout damage and to move forward with measures from the perspectives of both tangible and intangible elements.

Thus, this study firstly examined methods of identifying road bridges at greatest risk of scouring and washout damage due to flooding. In particular, it examined the potential for road bridges suffering damage from scouring and washout to connect this to the development of design and control methods, by performing factor analyses that accounting for mechanical processes based on action and resistance in the same way as the check formulas for performance in design standards, rather than being limited to statistical factor analysis. Next, it examined methods of improving the original location of bridges at greatest risk of washout so that the risk of disaster could be reduced without completely rebuilding the bridges.

2. Examining methods to evaluate disaster risk due to scouring

In relation to the mechanical process of scouring, we accounted for the dead load of the superstructure and the pressure of the flowing water as acting forces, as shown in figure 1. The hydrodynamic pressure was calculated assuming a flow velocity (V_{cr}) of 5 m/s from past measured cases of flow velocity in rivers in flood. As resistance, we accounted for the bearing power of the foundations. We allowed for the bearing power of the foundations to decrease as scouring proceeded. With these conditions, we worked backwards to calculate the flow velocity V_r when the bridge pier foundations reach their maximum strength, allowing for the effects of scouring.

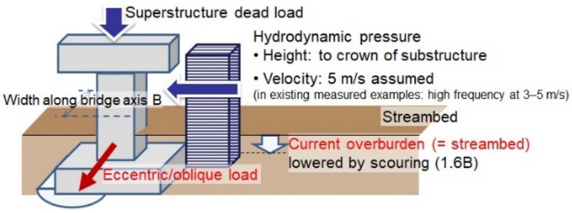

Fig. 1. Forces assumed when scouring occurs

Calculating the safety pertaining to scouring damage to be V_r/V_{cr}, we considered there to be a risk of disaster if the safety fell below 1 and calculated the scouring depth where the safety fell below 1 for each foundation form for 12 bridge piers with different foundation forms and ground conditions. We obtained calculation results suggesting that in the case of direct foundations, damage may occur when scouring reaches a depth of at least 1 m from the upper surface of the foundations. In the case of pile and caisson foundations, we obtained calculation results suggesting that damage may occur when scouring reaches a depth of at least half the length of the foundations.

These calculation results are based on various assumptions. We therefore investigated the overburden thickness and foundation depth before the disaster in the foundations of several road bridges that did or did not suffer damage in past flooding events. As a result, the bridges that actually suffered damage all met the conditions for damage obtained from the calculation results. Among the bridges that did not suffer damage, we observed some that did not meet the conditions for damage obtained from the calculation results, as well as some that did. The above suggests that the conditions for damage obtained from the calculation results are capable of assessing the potential for damage, erring on the side of safety.

3. Examining methods to evaluate disaster risk due to washout

In relation to the mechanical process for superstructure washout, we considered that the forces acting on the guard fence (railing), bridge shoe, and piers and the forces resisting them would be as in figure 2, and assumed that we would be able to gradually increase the flow velocity and develop explanations by computing the locations where the safety rate would first fall below 1 and the flow velocity at the time. This assumption was proposed based on the results of an analysis previously conducted by the Bridges and Structures Division on damage factors for road bridges due to tsunamis.1)

To verify the validity of the assumed model, we applied it to 20 bridges in the Kuma River catchment, where several bridges were washed out in the torrential rain in July 2020. As a result, we confirmed through calculations that in bridges where the superstructure was washed out, the shoe tended to be damaged before the piers collapsed or the guard fence was destroyed, for instance. In addition, the presence or absence of washouts matched the actual cases of damage.

Although this differed from the actual flood damage, we then assumed that all the bridges were inundated and converted the force acting on the shoes into lateral seismic coefficients to compare them with the design lateral seismic coefficients.

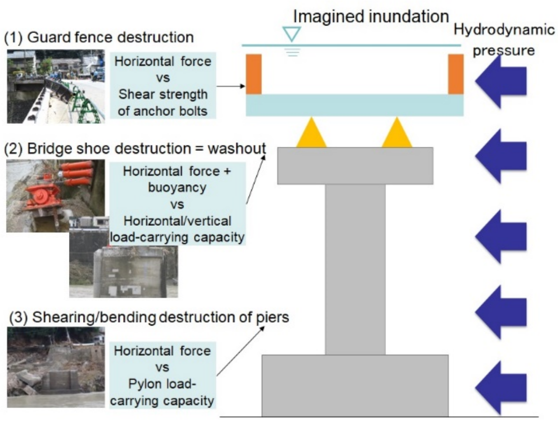

Fig. 2. Action and resistance of hydrodynamic pressure on bridge parts

We then used the flow velocity calculated backwards from the force of action calculated to wash out the bridge to find the design lateral seismic coefficients as converted from the force acting on the shoes for the case assuming that the bridge did not have a guard fence as well. The results of these calculations are shown in figure 3. As earthquake-resistant designs in past allowable stress methods have often expected the lateral seismic coefficient to be about 0.2, we have marked the figure with a red line at 0.2. We have also indicated whether each bridge actually washed out or not. The calculation results suggest that the shoes of the bridges that actually washed out may have experienced forces greater than the forces probably imagined in earthquake-resistant design. Moreover, we found that when we assume that guard fences were absent, the force acting on the shoes may lower to about the level considered in past earthquake-resistant design. In other words, introducing innovations in strengthening the shoes and in the structure of the guard fences through future technical development may reduce the potential for damage.

4. Conclusion

As an outcome of this research, we intend to submit the method of identifying bridges at greatest risk of scouring and washout to the Road Technology Subcommittee and proceed with examinations for creating a standard from it as a risk evaluation method or the like.

☞See here for detailed information

1) Concepts for Tsunami-Resistant Design Criteria for Coastal Bridges
https://www.pwri.go.jp/eng/ujnr/tc/g/pdf/29/29-6-1_shirato.pdf

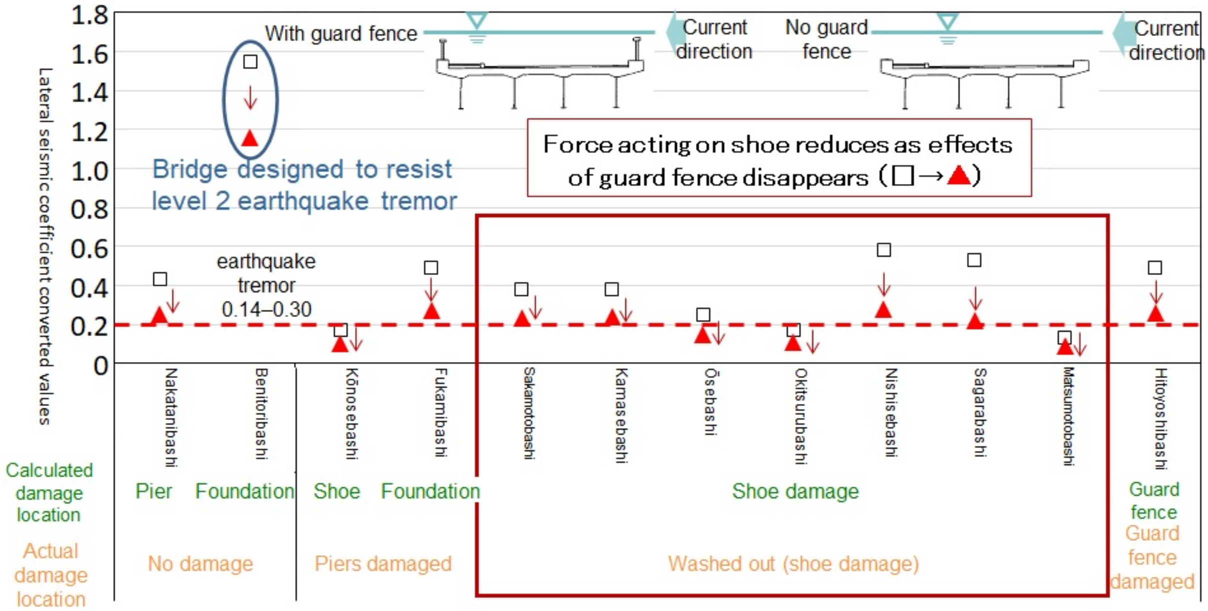

Fig. 3. Changes to acting lateral seismic coefficients depending on the presence of guard fences