Analysis of Bridge Girder Outflows due to Great Tsunami

Graduate School of Kyushu Institute of Technology Student Member ○Yulong ZHENG
Kyushu Institute of Technology Member Kenji KOSA
Nippon Engineering Consultants Co., Ltd Member Tatsuo SASAKI

1. Introduction

Triggered tsunami from the Great East Japan Earthquake caused tremendous destructions in eastern Japan. To study the outflow mechanism of bridges, outflows of 24 bridges (38 bridge girders) have been studied. Firstly, the evaluation results of bridge outflow by β ratio (ratio of girder resistance to tsunami impact) will be introduced. Secondly, basis and modification of drag coefficient will be discussed. In this part, we will study the variation of β ratio due to the modification. After the modification, the bridges flowed with β ratios greater than 1.0 will be evaluated. Further, Koizumi Bridge will be selected as a representative to check the reason combined with results from numerical simulation.

2. Evaluation Results of Girder Outflow

The bridge girders that flowed out is defined as Rank A while girders that survived as Rank C. As illustrated in Fig. 1, authors proposed the indicator β (S/F) to evaluate the girder outflows. S (S=μW, μ as friction coefficient) is the girder resistance. F (F= $1/2\rho_w C_d v^2 A$, v: velocity, use average as 6.0m/s; C_d: drag coefficient; A: impact area) is tsunami impact force. Fig. 2 illustrates the relations between β ratios and damage ranks. Average β of Rank A bridges with girders flowed is 0.84. Average β of Rank C bridges with girders survived is 1.52 (1.81 times of Rank A). Differences of β between Rank C and Rank A are obvious. Further, as to the detailed values, when β is greater than 1.41 (Max. of β for Rank A), bridges can be confirmed to survive; when β is smaller than 0.63 (Min. of β for Rank C), bridges can be confirmed to flow out. However, when β is located in the section between 0.63 and 1.41, β of Rank A and Rank C bridges are mixed together. Two possible reasons have been considered for this un-coinciding area. First one is the inappropriate use of drag coefficient and another one is the not uniform tsunami velocity as 6.0m/s.

3. Evaluation of Drag Coefficient

Fig. 3 presents basis for equation of drag coefficient. The data is from the wind tunnel tests conducted by the Public Works Institute of Japan. As illustrated in the Fig. 3, the proposed equation is a decreasing line before the B/D (Bridge width/height) as 8.0 to consider the safety factors; then, for agreement with equation from British Standard, a constant line was proposed after the B/D as 8.0. The evaluation results of β in Chap. 2 are based on this equation.

To prevent overestimations of drag coefficient, two modifications of the equation are conducted. First is by calculating the approximate line based on the average ($C_d = 1.929 - 0.133(B/D)$). As assumed in former research, girders with stretching part have the possibility to possess greater drag coefficient because vortex might

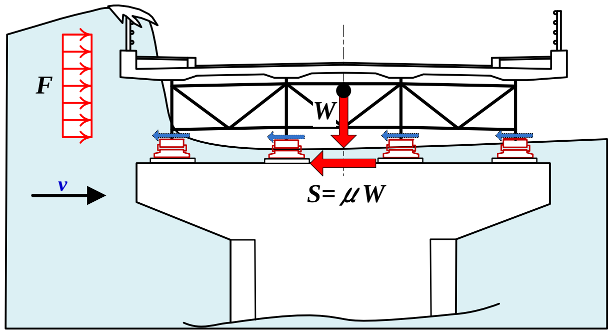

Fig. 1 Evaluation Model of β

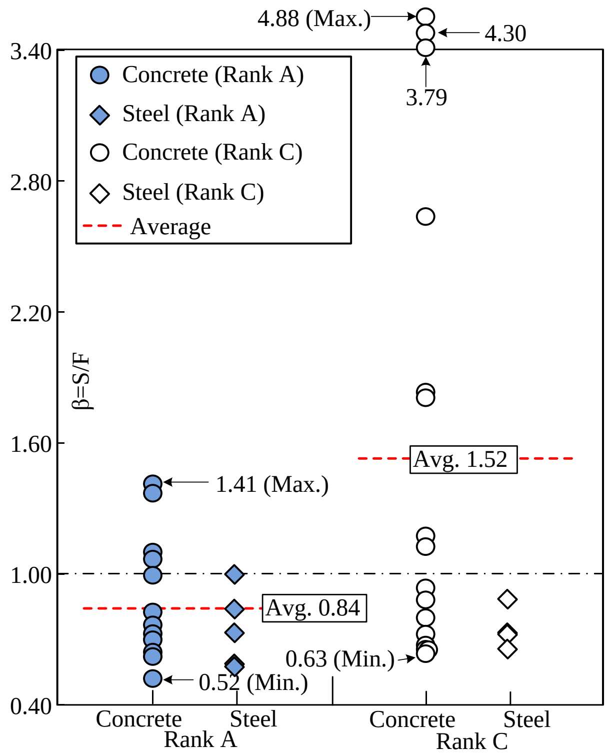

Fig. 2 Evaluation Results

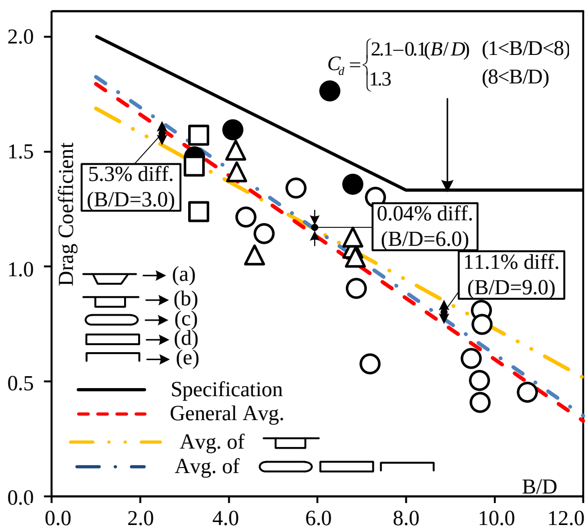

Fig. 3 Basis for Drag Coefficient

occur. To check whether this assumption is proper, the other modification is to classify the drag coefficients for girders with and without stretching part. From Fig. 3, it is known that no great difference has occurred. Similarly, no great difference generates compared to the general average. As a result, the authors will use general average equation for revising β ratios.

4. Evaluation of Results after Revising

As a representative, the comparison of β before and after revising for Rank A bridges is illustrated in Fig. 4. The average of β changes from 0.88 to 1.07 with 21.6% increase for concrete girders and varies from 0.75 to 0.90 with 20% increase for steel girders. For variations (a), (b) and (c), β becomes greater than 1.0. There are 7 β of Rank A bridges greater than 1.0 being difficult to reflect the outflow tendencies.

Another factor which may be influential on the un-coinciding β is evaluated. Fig. 5 presents the distance to coastal line and river width near the Rank A bridges. The L' is small with the average as 300.9m. As illustrated in former researches, tsunami velocity is decreased together with the tsunami propagation as the dissipation of energy. Thus, due to the smaller L' of the Rank A bridges, greater velocities were estimated. For the No. 4 and No. 5 bridges, although the L' are in medium level, river widths are great as around 200m, which make tsunami propagate more easily and greater velocities might be occurred. Therefore, because of possible greater velocities for Rank A bridges, tsunami impacts may be in greater level which will decrease the β.

As a result, due to different positions and terrains, bridges with un-coinciding β might have greater velocities than 6.0m/s. To analyze the actual velocity, we conducted the numerical simulation to Koizumi Bridge (No. 4 of Fig. 4) as a representative.

The nonlinear long wave theory is applied for the simulation. Fig. 6 shows the velocity distributions near Koizumi Bridge when maximum velocity occurred. Tsunami collects together in the river mouth from sea side. Due to the narrow terrain near the Koizumi Bridge, great velocity occurred. β change from 1.04 (v as 6.0m/s) to 0.70 (Max. v as 7.3m/s). Therefore, the Koizumi Bridge flowed out. Similarly, Rank A bridges with β greater than 1.0 have possibilities to have greater velocities. Through numerical simulations, more studies for the velocities should be conducted in future.

5. Conclusions

(1) Average β of Rank A bridges is 0.84. Average β of Rank C bridges is 1.52 (1.81 times of Rank A). Great difference occurred between different damage ranks. β ratios is efficient for evaluating girder outflows.

(2) Great difference of drag coefficients between girders with and without stretching part is not found. By revising β from drag coefficient, about 20% increase of β occurred.

(3) After revising β, 7 β of Rank A bridges are greater than 1.0. These bridges are discovered to mainly locate in smaller distance to coastal line, which would produce greater velocities. The β will also be decreased.

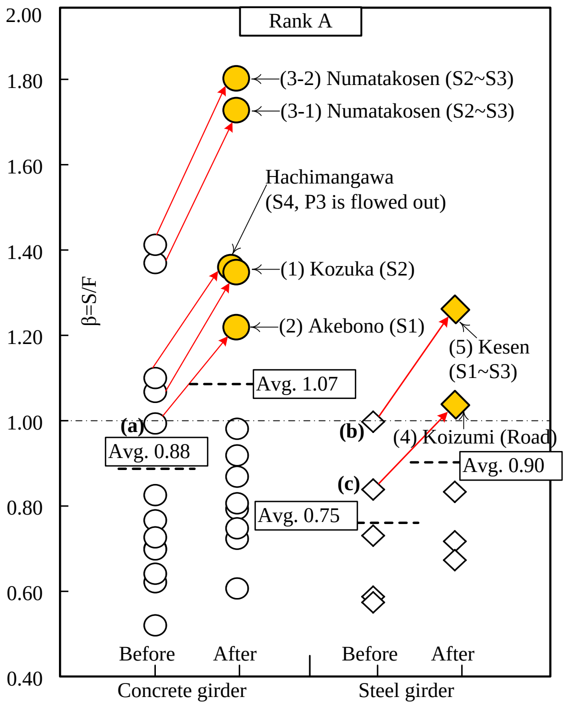

Fig. 4 Modification of β

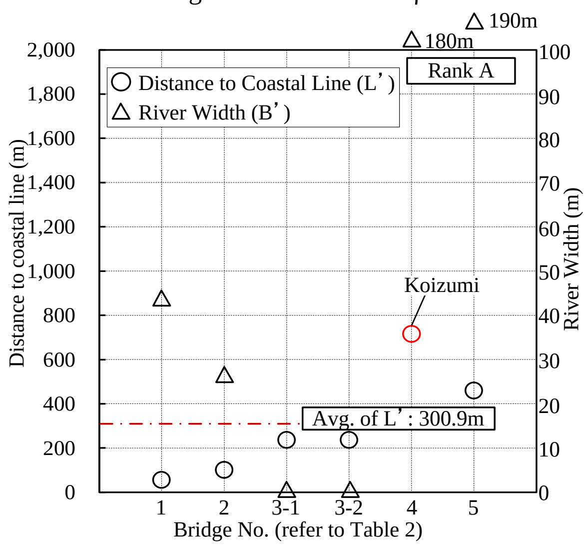

Fig. 5 Distance to Coastal Line & River Width

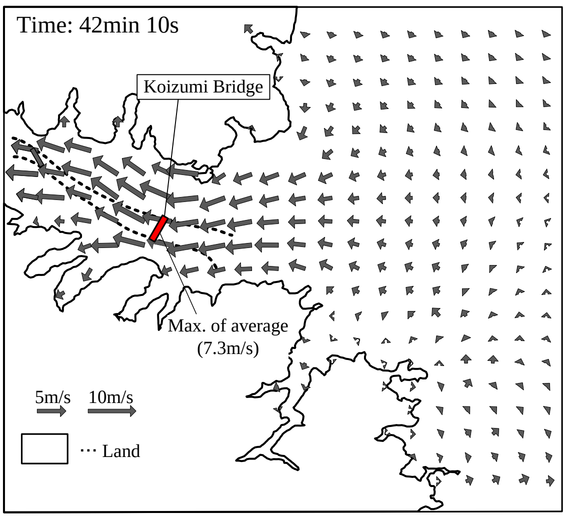

Fig. 6 Velocity Distributions near Koizumi Bridge