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“Technical Research and Development for Road Policy Quality Improvement” Study Summary

No.	Title	Principal Researcher
No.24-7	Research and Development on Tsunami-resistant Road Structures	Kyushu Institute of Technology Prof. Kenji KOSA

We attempted to develop a design method of bridges which are resistant to tsunamis. First, we grasped the mechanism of damage to bridges during the Great East Japan Earthquake by conducting field surveys and numerical simulations. Next, we carried out an experiment using a hydrologic model. Based on the overall results, we proposed a method to calculate the acting force and resistant force when the bridge is flooded by the tsunami.

1. Backgrounds and Objectives

Our research group received a research grant in 2007 through 2009 to study the damage to structures due to the tsunami triggered by the Indian Ocean Earthquake. As the fruit of this study, we grasped the mechanism how girders are washed away by the tsunami for the first time in the world, and received the MLIT Excellent R&D Award.

We applied this damage evaluation method to the structures damaged by the tsunami in the Great East Japan Earthquake with the aim of achieving two objectives: to establish a tsunami-resistant design method and to develop tsunami-resistant road structures.

2. Activities in Research Period

We took the following five steps to carry out the present study.

1) Evaluation of damage to road structures through field surveys
2) Detailed evaluation of damage in five areas through image & numerical analyses
3) Study of the damage process through hydrologic model experiments
4) Study of damage to the abutment and the damage mechanism
5) Proposal of the tsunami-resistant design method and protection measures

3. Study Results

1) Evaluation of damage

Figure 1 shows the results of detailed damage analysis targeting five areas. The tip of each bore type tsunami was 2 to 3 m high and they passed under the girder. The subsequent waves increased their height gradually at a ratio of 1-3 m/min and reached the girder position. The velocity at the time was 4-7 m/s. It was found that girders higher than 5 m were washed away by the steady flow-type tsunami whose water level rose gradually.

2) Tsunami-resistant design and protection measures

The tsunami shape is divided into the solitary wave type and the steady flow type. From the experimental results in Fig. 2 that used the former wave type, we can estimate the acting force per unit area of the girder. If we assume that a 5 m-high solitary wave accompanied by the 8 m/s steady flow acts on the girder of the Kesen Bridge, we can estimate the necessary resisting force. From this calculation, it was found that the wash-away of girders can be prevented if 24 concrete blocks are installed as shown in Fig. 3.

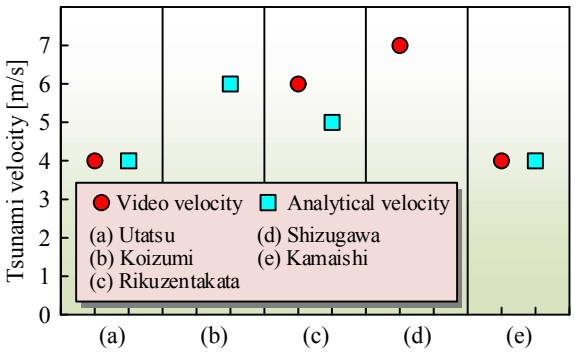

Fig. 1 Tsunami velocity distribution

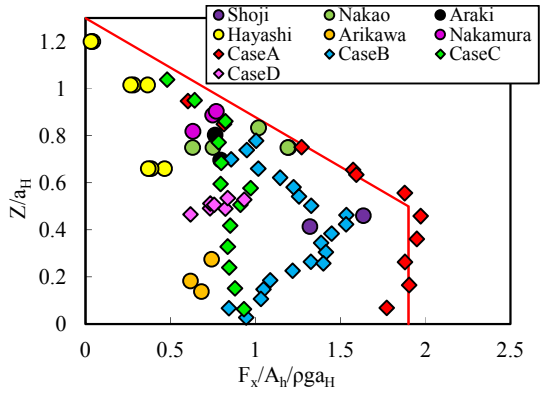

Fig. 2 Relationship between Fx and Z/ah

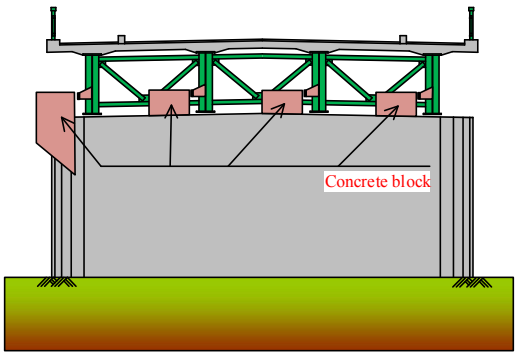

Fig. 3 Protective producer against tsunami

4. Papers for Presentation

20 papers, including the following, were published in the review-based journals in 2012 through 2014.

1) Sasaki, T., Kosa, K. and Zheng, Y.: Damage analysis of bridges based on the tsunami's acting force and the girder's resisting force, *Journal of St. Eng.*, Vol. 59A, pp. 417-427, 2013.
2) Fu, L., Kosa, K. and Sasaki, T.: Tsunami damage evaluation of the Utatsu Bridge by video and 2-D simulation analyses, *Journal of St. Eng.*, Vol. 59A, pp. 428-438, 2013.
3) Zheng, Y., Kosa, K. and Sasaki, T.: Tsunami damage analysis for bridges in the Shizugawa area, *Journal of St. Eng.*, Vol. 59A, pp. 439-449, 2013.

5. Study Development and Future Issues

Based on the present study, we proposed a standard evaluation method of the tsunami's acting force and the girder's resisting force when a bridge is flooded by tsunami waves. The proposed evaluation method can be used for various applications including the following.

1) Study on the projected Nankai and Tonankai Earthquakes.
   The damage mechanism of bridges and recommended protection measures were identified from the analysis of damage in the Great East Japan Earthquake. If we apply this knowledge to those projected earthquakes, we can estimate the degree of damage and propose protection measures.

6. Contribution to Road Policy Quality Improvement

The following two points are significant as the contributions to the road policy quality improvement.

1) A specific design approach was presented.
If the proposed design method is used, it is possible to calculate the design wave force using the girder height and the projected tsunami height. If the projected tsunami height is obtained, it is possible to evaluate the degree of danger of standard bridges.

2) Specific protection measures were presented.
It was found that the use of cables and anchor bolts is effective as the protection measures of the bridges evaluated as dangerous. It was also found that the concrete abutment is effective in protecting embankments from tsunamis. As seen, we can strengthen actual structures against tsunamis if we apply the proposed design method to those structures.

7. References, Websites, etc.

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