Evaluation of Tsunami Wave Forces on Railway Bridges

Ken WATANABE
Assistant Senior Researcher, Concrete Structures, Structures Technology Division

1. Introduction

Japan's east coast suffered tremendous damage, with many coastal railway bridges washed away, in the Great East Japan Earthquake. And, it is anticipated that the Tokai, Tonankai, Nankai Consolidated Type Earthquake will occur in the near future and might cause considerable damage to the railways along the coasts of Japan. Thus, RTRI has conducted evaluations of the forces applied by tsunamis in order to develop a method to predict tsunami damage to bridges and develop a countermeasure method for bridges to resist tsunamis in the future.

2. Outline of Evaluation

We conducted hydraulic tests and numerical analysis to develop a method to evaluate tsunami wave forces on bridge girders. For the girders in this evaluation, we fabricated three types of specimens, reduced to a scale of one-thirtieth of the actual size. These models were constructed to the typical parameters of the T-shaped, through girder and box girder cross-sectional shapes used on the railway bridges that washed out and collapsed in the Great East Japan Earthquake. Then we duplicated how tsunami-induced quasi-steady flow velocities acted, measured the drag and lift forces acting on the bridge girders, and performed detailed PIV (particle image velocimetry) analysis of the flow velocities around the test specimens using high-speed camera images. Two of the waveforms used for the test are shown in Fig. 1.
Fig. 2 shows cross-section shape of test specimen. Fig. 3 shows an example of the flow velocity distributions measured using the PIV, and the pressure distribution at the instant when the moment (M_{y0}) acting on the bridge girders has reached its maximum. In a bore where the water level rises in a relatively short period of time (Wave 14), generation of a high wave pressure was found on the upstream side, and the wave pressures acting on the floor slabs were unsymmetrical between the right and left. On the other hand, more uniform pressure was generated on the floor slabs in a split wave (Wave 15) though there were differences among the fluid forces acting on the sides. The difference between waveforms appears prominently in the moments and is considered to greatly affect girder stability. However, a downward force acted on the girders after the crest of the wave passed, which indicates that the risks of girder movement are high at the crest of a wave.

3. Conclusion

We understand the results of the tests and numerical analyses of the fluid action on bridges caused by tsunami waves and we determined the fluid forces acting on the girders depending on the shapes and dimensions of girders. In the future, we will conduct further studies to verify the effectiveness of reinforced concrete bridge structures to withstand tsunamis.

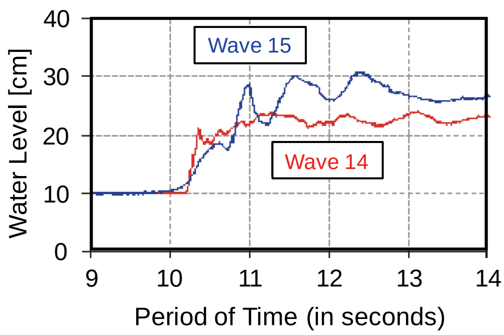
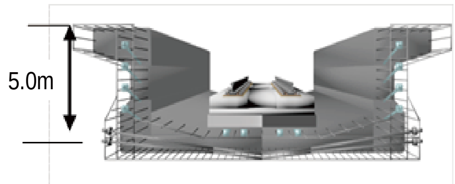


Fig. 1 Tsunami waveforms used for test



PC Through Girder

Fig. 2 Cross-section shape of test specimen

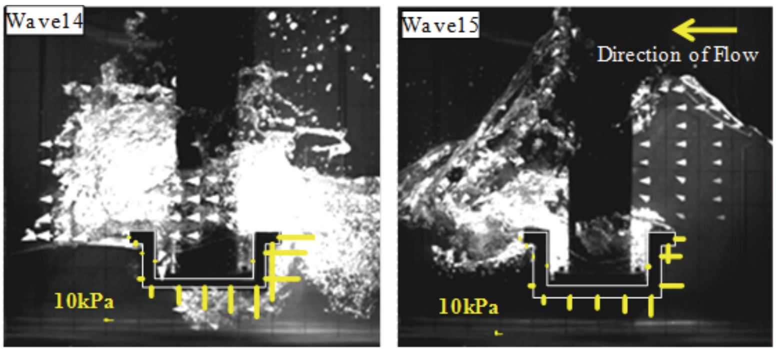


Fig. 3 Flow velocity distributions around girders measured using PIV and pressure distribution (at max. moment (M_{y0}))