Research Project Highlight

Tsunami-borne Debris Loading on Bridges

TSRP Topic A1 - Tsunami & performance evaluation of ports and bridge design

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Start-End Dates:
5/1/2019-4/30/2021

Abstract

Widespread damage to coastal bridges in recent tsunamis (Indian Ocean, 2004, and East Coast Japan, 2011) have shown the vulnerability of these structures to tsunami overtopping and the crippling socioeconomic impact of their loss on both emergency response and long-term recovery of the affected communities. Developing design guidelines for coastal bridges subject to tsunami overtopping has therefore become a priority and large-scale experimental and numerical simulations have been conducted to develop and validate tsunami design equations. But this work has been limited to clear-water conditions. The goal of the present effort is to study the effect of tsunami-borne debris on design loads for bridges using the Large-Wave Flume at Oregon State University in Corvallis. This work will be informed by high-end numerical simulations. Experimentally-validated tsunami debris load equations will then be developed including adjustment factors for debris, and these will be used to evaluate (a) available simplified equations for debris loading on buildings (ASCE 7, FEMA P-646), and (b) the simplified debris loading equations for bridges recently developed using engineering judgment in the PEER pooled-fund, design guideline project for coastal bridges (TPF-5(307)). Major deliverable will be a set of validated adjustment factors for use in design load equations for bridges to include the effect of tsunami-borne debris.

Deliverables

A PEER report and several conference and journal papers describing the (a) pre-test numerical simulations, (b) setup and results from the experiments in the Large Wave Flume at Oregon State University, (c) evaluation of existing debris load equations and development of revised adjustment factors for debris as necessary, and (d) recommendations to AASHTO Committee on Bridges and Structures

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regarding potential revisions to the design guidelines for coastal bridges developed in the PEER pooled-fund project TPF-5(307).

Research Impact

Widespread damage to coastal bridges in recent tsunamis (Indian Ocean, 2004, and East Coast Japan, 2011) have shown the vulnerability of these structures to tsunami overtopping and the crippling socioeconomic impact of their loss on both emergency response and long-term recovery of the affected communities. Developing design guidelines for coastal bridges subject to tsunami overtopping has therefore become a priority and large-scale experimental and numerical simulations have been conducted to develop and validate tsunami design equations. But this work has been limited to clear-water conditions. The goal of the present effort is to study the effect of tsunami-borne debris on these design loads using the Large-Wave Flume at Oregon State University in Corvallis. This work will be informed by high-end numerical simulations. In particular, the objectives of this study are to:

A. Understand the two-fold effect of debris: (a) impact and (b) damming on bridges, for (i) small-size debris objects such as construction material, and (ii) large-size debris objects such as containers and ships.
B. Examine the effect of multi-object debris, which is a more realistic case than single-object debris.
C. Decipher (a) debris-wave interaction during debris transport, and (b) debris-wave-bridge interaction during the tsunami inundation of two types of bridges, a T-girder and a box-girder bridge. Although both types of bridges are expected to sustain the same impact force, the damming force could change, especially for small-to-moderate sized debris trapped between the girders of a T-girder bridge.
D. Develop a high-quality experimental database that could be used by PEER and other research teams around the world for development and validation of numerical tools, to advance PBTE for coastal bridges.
E. Develop and test possible counter-measures for new and existing bridges against debris loading.
F. Contribute to the development, calibration and validation of the particle finite element method (PFEM) in OpenSees for simulating the tsunami debris impact on bridges.
G. To the extent possible, compare results mesh-based (FEM), particle-based (SPH) and hybrid particle-mesh based method (PFEM) numerical methods for simulating (a) debris transport, (b) debris impact, and (c) debris damming, and identify the limitations of each method
H. Evaluate (a) available simplified equations for debris loading on buildings (ASCE 7, FEMA P-646), and (b) the simplified debris loading equations for bridges recently developed using engineering judgment in the PEER pooled-fund, design guideline project for coastal bridges (TPF-5(307)).

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Project Images

Single span bridge model being installed in Large Wave Flume at Oregon State University. Photo credit: Ian Buckle

Tsunami from Great East Japan Earthquake coming ashore near Sendai, Japan, March 2011. Photo Source: Mark Yashinsky.

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