DRISI

Caltrans Division of Research, Innovation and System Information

Research Results

Seismic

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Project Title:
Tsunami Forces on Selected California Coastal Bridges

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Are California's Bridges Vulnerable to a Tsunami?

Developing models to measure the impact of tsunami forces on coastal bridges

WHAT IS THE NEED?

Past studies have examined how bridges perform during earthquakes, hurricanes, and storm surges, but few comprehensive studies have measured tsunami forces on coastal bridges. Some bridges that have withstood earthquakes were later washed away after a tsunami hit, indicating that current design specifications might not provide bridges with sufficient resilience to resist tsunami loads. Most investigations have been either surveys that explained the failure mechanisms after a tsunami or small-scale experimental studies that oversimplified wave types and bridge configurations. Each tsunami contains multiple wave types, from a solitary wave to a complex pattern of breaking waves, all of which can impose a wide range of loads on bridges.

Tsunami-resistant design criteria for coastal bridge superstructures that address factors such as how large a wave is required to cause a bridge collapse and whether existing box girder bridges are vulnerable to damage from tsunamis is needed.

WHAT WAS OUR GOAL?

The goal was to determine how vulnerable California coastal bridges are to tsunamis and how to modify design codes to mitigate or avoid extensive damage.

WHAT DID WE DO?

Caltrans, in partnership with the Oregon State University School of Civil and Construction Engineering, measured the effect of tsunami loads on five California coastal bridges. The researchers calculated the maximum horizontal and vertical loading on a bridge superstructure in a tsunami. Both the initial impact and total inundation time periods were considered, with the entire process modeled in simulations.

Tsunami flow durations usually span hours. To capture the behavior of the structure under several impacts and inundations over the full duration, multiple time periods were analyzed. For each tsunami flow condition, the forces and moments were computed for four selected time periods containing initial impact, occurrence of the maximum tsunami water velocity, occurrence of the maximum tsunami momentum flux, and occurrence of the maximum tsunami mass flux.

The researchers developed finite-element (FE) analysis codes to compute tsunami loading on the selected bridges and validated the outcomes using experimental results of hydrodynamic loads on inundated bridges. The team used tsunami input data sets provided by Caltrans to generate the tsunami flow field in the vicinity of the bridges. Tsunami horizontal and vertical forces and moment time histories were obtained using the FE codes.

WHAT WAS THE OUTCOME?

The researchers developed formulas to estimate tsunami loading on bridges. Comparisons between numerical results from simulations and the estimated forces provided
some data to evaluate bridge vulnerability. The research recommends conducting large-scale, wave-tank testing to validate and calibrate these equations.

Tsunami-bridge interactions generally occur in two phases: the initial impact between tsunami water with the seaward side of the bridge cross-section, and the phase in which the tsunami has completely inundated the bridge. The team learned that the initial stage includes a combination of horizontal and uplift forces. Maximum uplift force at the first wave impact occurs when the water reaches the top of the bridge barrier, just before it flows onto the bridge deck. During that stage of loading, horizontal and uplift forces gradually increase, causing the overall maximum uplift force to occur when the bridge superstructure is already inundated. The next step is to conduct wave-tank studies to validate the analytical work.

WHAT IS THE BENEFIT?

Determining the vulnerabilities of California's coastal bridges to tsunamis is a first step to avoiding bridge failures. A reliable tsunami-resistant design criterion for coastal bridges is crucial. The equations developed are analytical predictions to determine tsunami loading on bridges, enabling Caltrans to assess if coastal superstructures are vulnerable to tsunamis and how tsunami loads compare in magnitude to forces generated by strong shaking.

LEARN MORE

To view the complete report:
www.dot.ca.gov/research/researchreports/reports/2013/final_report_65a0384_task_1983.pdf

IMAGES

Figure 1: Location of Malibu Lagoon Bridge