Transportation Consortium of South-Central States (Tran-SET)

Coastal Bridges under Hurricane Stresses along the Texas and Louisiana Coast

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Project No. 17STTSA02

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Developing a bridge-response model to mitigate risk and improve resiliency

The main objective of the research is to develop a high-resolution model capable of simulating the response of bridge structures to hydrodynamic loads for hurricane design conditions (i.e.,surge height, wave height, and frequency) expected in the Texas-Louisiana coast.This model will be calibrated using historical data from past hurricanes such as Katrina and used to evaluate the vulnerability bridge structures on the Texas-Louisiana coast. The implementation phase will consist of developing a guide for engineering professionals illustrating regions of greatest hazard and bridge support details most vulnerable to failure during large storms.

Problem Statement

The societal cost of natural disasters can be significantly decreased through planning for resilience instead of accepting the risk and repairing the damage. For example, Padgett et al. (2009) indicate the cost of repairing and replacing bridges damaged during hurricane Katrina exceeded 1 billion dollars, and their review of the damage reports showed that this cost could have been significantly reduced by implementing relatively simple mitigation measures.

The most severe damage consisted of superstructure collapse due unseating of the deck, which was induced by the combined actions of storm surge and hydrodynamic forces from waves. This type of failure was observed both in bridges with integral and non-integral supports, which shows that in some instances uplift forces were large enough to exceed the weight of the superstructure and cause failure of the connection at the support. Studies that document damage from major hurricanes provides a valuable source of information to study the risk to bridge infrastructure due to hurricanes. While empirical observations are useful, there is a need to develop scientific models capable of simulating fluid-structure interaction under the combined actions of storm surge and waves so that the risk can be quantified through a scientific rather than empirical approach.

Summary

This project aims to model the hydrodynamic conditions along the Texas and Louisiana coasts during hurricane events. The surge and wave conditions around coastal bridges will be determined using historical data and the results from similar studies. The simulation analysis will provide the hydrodynamic estimations that are useful in assessing/predicting the response of coastal bridges that may come under extreme stress during such events. Given the one-year duration of the proposed project, first-order hydrodynamic information will be used to assist in the development of the bridge response assessment framework and conservative bridge response estimates. Such analysis would also help find hot spots for hurricane stresses on coastal bridges along the Texas and Louisiana coasts. In future studies, the model will be progressively refined for the hydrodynamic conditions (and hence bridge responses).

Findings

A high-resolution FE model was created to simulate the hydrodynamic forces caused by waves impacting on bridge girders. The model relied on Coupled Eulerian-Lagrangian techniques (CEL) where solids are simulated with Lagrangian meshes while fluids are simulated using Eulerian meshes, as shown in Figure 1.

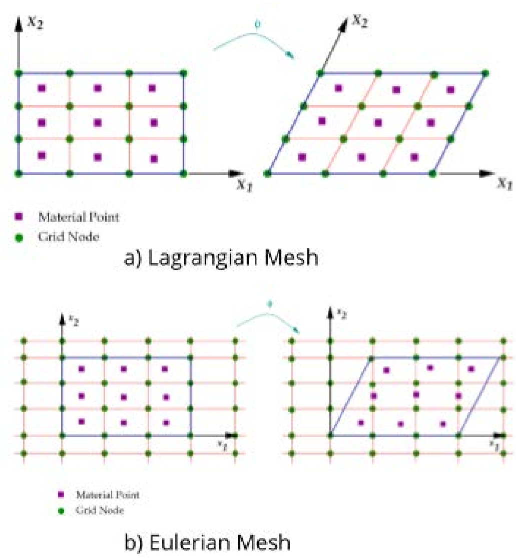

Figure 1. Eulerian and Lagrangian meshes.

Lagrangian meshes are attached to material points, and as materials deform, the mesh deforms with them. In contrast, Eulerian meshes remain the same as the material flows (or deforms) within the mesh. The extent of deformation in this case is measured when the material particle flows across an element node (it acts as a background grid).

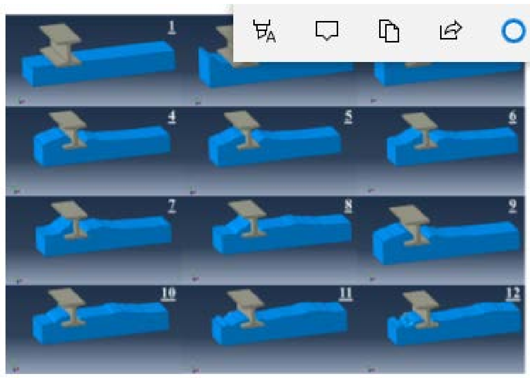

Figure 2. Modeling of a wave impacting a bridge girder.

Results from the simulations are shown in Figure 2. A wave is simulated by inducing an initial velocity in the fluid, at the edges of the domain. Variations in wave properties (wavelength and amplitude) are introduced by adjustments in the boundary conditions of the fluid domain. The model is being validated by calculating buoyancy forces induced by simple variations in fluid height, and by comparing hydrodynamic forces with existing data sets and classical solutions.

Impacts

The research addresses a knowledge gap by developing a new model to simulate complex interactions between bridges, storm surge, and waves.A model of this type will permit studying the effect of hydrodynamic forces characteristic of the Texas-Louisiana Gulf coast, which will help identify bridge structures with the greatest risk of collapse due to unseating during hurricanes.

Tran-SET

Tran-SET is Region 6's University Transportation Center. It is a collaborative partnership between 11 institutions (see below) across 5 states (AR, LA, NM, OK, and TX). Tran-SET is led by Louisiana State University. It was established in late November 2016 “to address the accelerated deterioration of transportation infrastructure through the development, evaluation, and implementation of cutting-edge technologies, novel materials, and innovative construction management processes”.

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For more information about Tran-SET, please visit our website, LinkedIn, Twitter, Facebook, and YouTube pages. Also, please feel free to contact Mr. Christopher Melson (Tran-SET Program Manager) directly at transet@lsu.edu.

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