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# BARGE IMPACT TESTING OF THE ST. GEORGE ISLAND CAUSEWAY BRIDGE, PHASE I : FEASIBILITY STUDY

## PROBLEM STATEMENT

The loads that may be imparted to a bridge during potential ship and barge impact events must be carefully considered during the design and evaluation of bridge structures that cross navigable waterways. While bridge design documents, such as the AASHTO *Guide Specification and Commentary for Vessel Collision Design of Highway Bridges*, address these issues with code-based loading conditions, very little actual impact test data has ever been recorded for such events. Given the large number of bridges in Florida that cross navigable waterways, FDOT has a need for reliable and accurate barge impact-loading data for use in bridge design, retrofit, and evaluation. "Accurate," in this context, is taken to mean that the lateral impact loads used for design are not unconservative, but are also not so conservative that they result in needlessly expensive bridge designs.

The replacement of the SR 300/Saint George Island Causeway bridge near Apalachicola, Florida with a new bridge structure represents a unique and valuable opportunity to experimentally measure barge impact forces directly. After opening the new bridge to traffic, the older structure will be impacted by a hopper barge and the lateral forces imparted to the bridge piers will be directly measured.

## OBJECTIVES

This project is multiphasic: the purpose of Phase I was to determine the feasibility of conducting the full-scale experimental test program on the bridge and to establish the parameters of that test program. Researchers investigated environmental, geographical, and scheduling feasibility of conducting the test program. Nonlinear dynamic finite element modeling of hopper barge impacts on bridge piers was conducted using LS-DYNA to study the character (magnitude and time variation) of the impact loads and to establish the impact velocities to be used in the physical test program.

In order to achieve these objectives, a number of different tasks were included in the scope of work for this phase:

- Conduct a review of the current AASHTO barge impact provisions.
- Conduct a literature search for any published papers describing previously carried out experimental barge impact testing programs.
- Generate a list of areas to be studied in order to determine whether or not the proposed testing is feasible. Outline a testing program that maximizes the usefulness of the data collected while also maximizing the probability of success with respect to permitting, scheduling, costs, and other contributing factors.

- Review pertinent environmental permitting issues including oyster beds, manatees, protected bird estuaries, noise restrictions, and water turbidity restrictions. This task also included discussions with the contractor that is building the new bridge, and a review of the contractor's environmental permitting documents.
- Select the most appropriate type and size of barge, obtain cost estimates for new and used barges, estimate time required for barge acquisition, and determine tug requirements for navigating the test barge during impact testing.
- Review water depth data for the area near the existing and new bridge structures, conduct an onsite bathymetric survey to directly evaluate water depths, and determine most appropriate barge acceleration paths considering new bridge location, water depth data, and presence of other features such as oyster beds and power lines.
- Develop a schedule for the full-scale testing and examine the sensitivity of the schedule to unforeseen delays. Meet with the contractor handling the demolition of the existing structure to determine the feasibility of performing the testing without interfering with the overall bridge replacement process.
- Develop finite element models of a hopper barge and of selected piers in existing St. George Island causeway bridge structure using construction plans and available soil data. Pier models include the pier structure, pile cap, piles, and soil springs.
- Using the barge and pier finite element models, conduct numerous simulated impact scenarios. The goal is to choose a barge size and cargo mass that maximizes the variety of impact loads that can be imparted to the bridge while still ensuring safety. These models will also be used in subsequent phases of the project to design and develop instrumentation systems for measuring the impact loads.

## FINDINGS AND CONCLUSIONS

Results from the study indicated that the proposed impact testing program is feasible with respect to all areas investigated. Specific results from the feasibility study included the identification of an overall time window for the full-scale testing, testing location, barge acceleration path (based on a water depth survey that was conducted at the bridge site), and a preliminary selection of test conditions (barge mass, impact velocities, etc.) to be used in the full-scale test program. Dynamic finite element impact simulations were conducted using LS-DYNA for a variety of different impact scenarios in order to study and characterize barge impact loads. In addition, static crush simulations were conducted in order to relate barge deformation to crush force.

Results from the simulations (both dynamic and static) were compared to the AASHTO barge impact provisions. For moderate velocity impact conditions typical of piers near a navigation channel, the loads predicted by the AASHTO provisions were larger than those predicted by finite element impact simulation. The magnitudes of these loads through time remained somewhat constant, which is consistent with the AASHTO method of using equivalent static loads for lateral load design. For low velocity impacts, the loads predicted by AASHTO were significantly smaller than those predicted by simulation. In addition, for such cases, the impact loads exhibit significant dynamic oscillation through time, and the use of an equivalent static load approach is less applicable.

# BENEFITS

The findings of the feasibility study allow the FDOT to proceed with confidence to the physical testing phase of the research. This study showed that physical testing will add useful information to our current knowledge base and that this testing can be completed in a time frame that will not conflict with the bridge contractor's schedule for removal of the existing bridge.

The results of this research program will likely yield information that will influence bridge design codes throughout the world. The current codes may be modified to produce vessel collision force results that better predict actual impact forces. Moreover, the research results will assist engineers of many disciplines. For example, the geotechnical engineer will better understand the stiffening effect pore water provides when soil is rapidly loaded, and the bridge designer will better understand how to model a bridge to achieve the correct distribution of load to an impacted pier and to predict the loads shed to the adjacent piers. The bottom line, however, is that the knowledge gained through this research may save lives by resulting in a better understanding of the vessel impact event.

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