BARGE IMPACT TESTING OF THE ST. GEORGE ISLAND BRIDGE

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Why FDOT Promoted And Funded This Research:

The highest priority of the Florida Department of Transportation (FDOT) is to provide a safe transportation system. The next highest priority is to spend valuable tax dollars wisely. These two priorities are the motivation for this research, the goal of which is to provide a consistent safety standard at an appropriate cost. The majority of commercial waterborne traffic in Florida consists of barges that navigate the intracoastal waterways. Typical design impact forces for bridge channel piers vary from one to four million pounds lateral force. The design forces diminish gradually as a function of distance from the vessel channel; however, the vessel impact forces usually control the entire bridge design concept and, thus, construction costs. This situation is easily understood when one considers that, in the absence of vessel impact, the controlling lateral forces are hurricane wind forces and that these forces are only on the order of 60 to 150 thousand pounds per substructure unit or pier. The basis for determining the barge impact design forces, which in turn control safety and cost, is the methodology outlined in the AASHTO LRFD Bridge Design Specifications. FDOT considers this methodology to be an excellent and practical approach to quantifying a design force that is based upon statistical as well as structural concepts. The equivalent static impact forces derived from the Specifications are, however, based upon very limited existing data and not upon any actual full-scale barge collision events with bridges. It is universally understood in the bridge design community that full-scale impact testing would provide beneficial knowledge and allow for further refinement of the existing code methodologies.

An Unusual Opportunity Avails Itself

A new bridge connecting East Point (near Apalachicola in the Florida panhandle) to the St George Island Bridge will be completed and open to traffic late in 2003. The existing bridge will be demolished and used to create artificial fish sanctuaries. An opportunity to conduct full-scale barge impact tests on the existing bridge presented itself for a number of reasons. First, a distance of 2000 feet at the barge channel separates the new and existing bridge alignments and so provides a safe operation zone for the test barge. Second, the bridge contractor, Boh Brothers Inc, was interested in assisting FDOT with this important research. Third, the demolition schedule allowed for the impact testing to be conducted with minimum delays to the contractor. Finally, water depths allow for the testing of two types of bridge piers, a mudline foundation on steel piles and a waterline footing on concrete piles.

Overview of the Research to Date

FDOT contracted with the University of Florida (UF) to conduct this research. The following three-phase plan was developed:

Phase 1: A feasibility study. This study concluded that the time frame for the test was sufficient and that the test program results would likely provide data that could be used to enhance the current design methodology. Items of primary interest include the crush depth to force relationship of the barge itself and the comparison of dynamic test results to the equivalent static force method being employed for practical bridge design applications. The response of the soil to the rapid loading from an impact type loading is also of importance to FDOT, because the structural computer program FBPIER, used for bridge design, includes non-linear springs that simulate soil behavior. It is likely that these soil springs should be stiffened for the application of a rapid loading condition. The question is, how much should they be stiffened?

Phase 2: Preparation and prototype testing. Tasks in this phase included obtaining environmental permits, developing and prototype testing instrumentation packages, taking field measurements and evaluating the strength of the existing bridge structure, performing numerical simulation of proposed impact tests, acquiring a test barge, and developing the soil exploration and instrumentation program.

In order to numerically study the magnitude and time variation of impact forces that occur during barge impact events, UF developed finite element models of a typical jumbo hopper barge, as shown in Figure 1. The researchers are currently refining this model to simulate the exact structural configuration of the barge to be used and supplied by the bridge contractor. A method of approximately representing buoyancy effects using discrete spring elements was used to support the barge at the appropriate elevation during impacts; gravitational body forces were also represented.

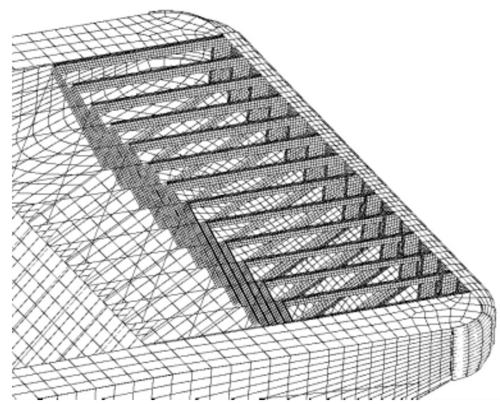
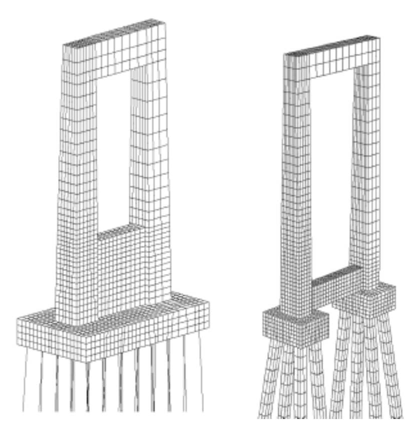


Figure 1. Bow section of barge model (deck plate removed to show internal trusses)

Finite element models of two reinforced concrete bridge piers (see Figure 2) were developed using available structural plans and soil data.

A series of barge-to-pier impact scenarios were then simulated using each pier model, various impact speeds (1, 2, 4, and 6 knots), and various barge masses (empty, half loaded, and fully loaded). Contact forces developed between the barge bow and the pier columns were then extracted from the simulation results and plotted versus time. Such time-history plots of lateral impact load revealed that the load magnitude is dependent on the relative stiffness between the barge bow and the bridge pier. Substantial vessel deformation can occur during barge impacts (Whitney et al. 1996), and the resulting energy dissipation and contact force development are related to this crushing deformation (see Figure 3).

Figure 2. Pier-1 with steel piles (left) and Pier-3 with concrete piles.



In several simulations, doubling the impact velocity resulted in a longer duration of sustained load but only a moderate increase in peak load magnitude. However, changes in lateral stiffness of the pile-foundations resulted in significant changes in both peak load developed and rate of load decay through time. Of particular interest in this study were cases involving typical barge-traffic impact velocities and typical impact resistant pier configurations. Preliminary simulations of high energy, severe impact cases indicate that the load histories developed can be reasonably approximated using equivalent static loads—i.e. the approach used by AASHTO. Further simulations are being conducted to determine whether the *magnitudes* of loads developed in the simulated scenarios agree with the magnitudes predicted by AASHTO.

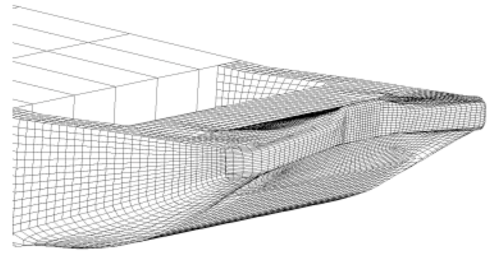
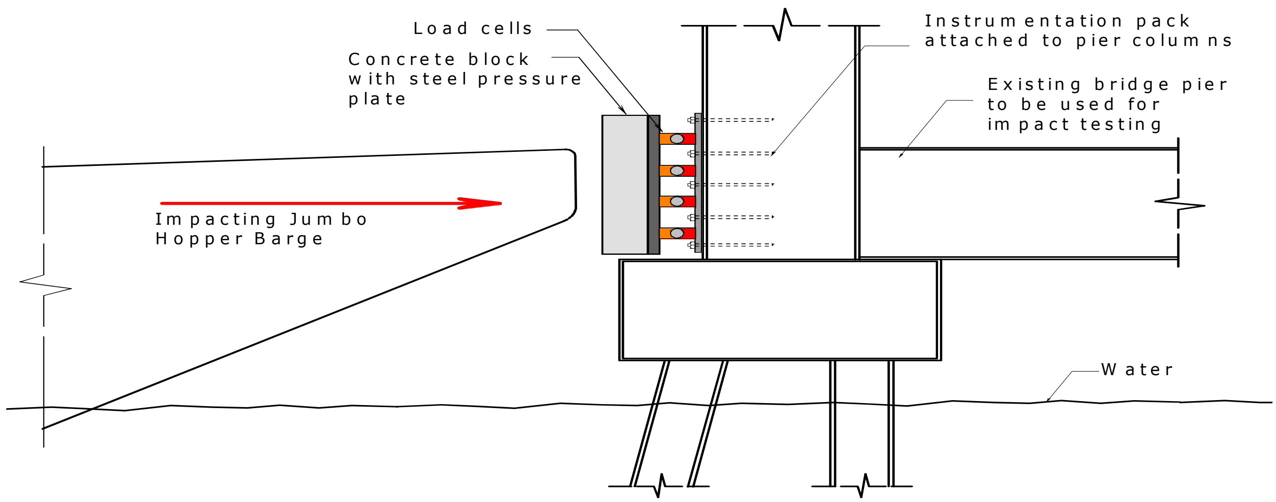


Figure 3. Deformation in barge headlog caused by a 4-knot impact on Pier-1

Phase 3: Full-Scale Barge Impact Tests. It is anticipated that the impact tests will take place in November or December 2003. Two pier types will be instrumented and subjected to a series of impacts at velocities yet to be determined. Completion of the finite element modeling of the test barge is still needed in order to determine appropriate test velocities. The intention is to gain as much information as possible about the forces and deformations without actually causing a pier to collapse (we do not wish to block the shipping channel). The load cell array with impact block, shown below, will allow for direct force measurements. Tests will be made with and without superstructure sections in place so as to determine the component of impact force being shed through the superstructure to adjacent piers.



Expectations Upon Completion of the Research:

Refinements and improvements to the existing AASHTO design code.

A new and relatively simple dynamic design approach to vessel collision will be formulated and presented for use as an alternate to the equivalent static method.

The non-linear soil springs used in the FBPIER design software will be modified to in order to simulate the effects of a rapidly applied load.

A significant contribution to the general understanding of structural dynamics, which will, no doubt, be of interest to engineers and scientists all over the world.

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