Summary of Final Report, BC354-76
March 2006

BARGE IMPACT TESTING OF THE ST. GEORGE ISLAND CAUSEWAY BRIDGE, PHASE III: PHYSICAL TESTING AND DATA INTERPRETATION

PROBLEM STATEMENT

Bridges spanning navigable waterways are, by virtue of their locations, inherently at risk for collisions with errant transport vessels such as barges. Given these risks, lateral loads associated with vessel collisions must be quantified for use in structural design. Typical bridge design involves the use of barge impact provisions published by AASHTO to determine equivalent static impact loads. However, few experimental studies have ever been conducted to quantify, via direct experimental measurement, the loads that are transmitted to pier, foundation, and superstructure elements during barge collision events. Consequently, the data available for use in developing design provisions are extremely limited. The AASHTO barge impact provisions, for example, were developed using experimental data from pendulum impact hammer tests conducted on stationary, reduced-scale (~1:5) physical models of barges. Pendulum tests on stationary vessel models fail, however, to include dynamic interaction effects that occur between barges and bridge piers during real collision events. As a result, the accuracy of the equivalent static load levels stipulated by AASHTO has been unknown. Employing full-scale experimental testing to quantify the dynamic impact loads that are generated on bridge piers during typical barge collision events would help to ensure that bridges in Florida are designed in a manner that is both safe and economical.

OBJECTIVES

Replacement of the old (now demolished) St. George Island Causeway bridge near Apalachicola, Florida provided a unique opportunity to conduct full-scale experimental barge impact tests on instrumented pier structures. During each impact test, sensor arrays and high-speed data acquisition systems were used to directly quantify dynamic impact loads and resulting structure, soil, and barge responses. The primary objectives of this data collection process included the following:

1. To quantify the dynamic impact loads that were imparted to the test piers, and to compare the measured values to loads calculated using the AASHTO barge impact provisions.

2. To quantify pier and superstructure responses to the barge collision loads.

3. To quantify load-deformation (force-crush) relationships for the test barge and to compare the measured relationship with the AASHTO barge impact provisions.

4. To quantify the relative magnitudes of displacement, velocity, and acceleration proportional sources of resistance that were mobilized during dynamic barge collision tests.

5. To determine whether soil response to vessel impact loading is sufficiently described using static load-deformation relationships or whether dynamic sources of soil resistance are important.

6. To compare structural demand indices produced from static (AASHTO) and nonlinear dynamic analyses of piers subjected to corresponding loading conditions.
7. To recommend parameters that should be taken into consideration in the future development of new barge impact design provisions.

FINDINGS AND CONCLUSIONS

Direct examination of experimental data and comparisons of experimental data with numerical analysis results led to the following findings and conclusions:

- In moderate to high energy impact conditions, the maximum impact loads that can be generated during a collision are limited principally by the load carrying capacity of barge bows.
- The AASHTO barge width modification factor was found to be inconsistent in comparison to data measured experimentally.
- Substantial levels of impact resistance can be generated by soil forces acting directly on surfaces of buried foundation elements such as pile caps and tremie seals.
- Under rapidly applied impact loads, dynamic components of total soil stiffness can be as large as, or larger than, static components.
- Mass-proportional inertia forces can significantly influence pier response to barge impact loads.
- Static design loads specified in the AASHTO barge impact provisions for moderate to high energy impacts on stiff piers were found to be substantially larger than corresponding impact loads measured experimentally.
- Static design loads specified in the AASHTO barge impact provisions for low-speed, low-energy impacts—typical of the “drifting barge” impact condition—on flexible piers were found to be smaller than the impact loads measured experimentally.
- Pier cap restraint associated with superstructure resistance, particularly mass-proportional inertial resistance, can result in considerable dynamic amplification of pier column design forces.

BENEFITS

Results from this research indicate that changes to existing barge impact load calculation provisions are desirable, both from the standpoints of safety and economy. Data collected during this study has been used to validate existing pier analysis software packages, and will be used in the near future to develop updated design provisions and updated analysis procedures for assessing structural response to barge impact loads.

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