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# BARGE IMPACT TESTING OF ST GEORGE ISLAND CAUSEWAY BRIDGE GEOTECHNICAL INVESTIGATION

## PROBLEM STATEMENT

Generally, vessel impact considerations control the design of bridges over navigable waterways: i.e., 40% to 80% of pier loads are transferred to the deep foundation system. Current AASHTO vessel impact design guidelines (1991) compute the equivalent static load acting on a bridge based on the calculated kinetic energy (mass and velocity), but they do not consider dynamic forces (inertia and damping). Depending on the duration of impact, particle velocities, accelerations, and size or zone of soil mass, the dynamic resistance may be significant. The disassembly of the old St. George Island Causeway Bridge provides an opportunity to study the actual effects of a vessel impact: the inertia and damping provided by the soil-structure system. An impact test would also provide an opportunity to evaluate how well existing software (i.e. FB-Pier and LS-Dyna) models substructural time domain response.

## OBJECTIVES

The objectives of this research were to assess the properties (i.e. strength, stiffness, and damping) of the soils at St. George Island Causeway Bridge, and to monitor and model the soil-structure interaction of the channel and approach piers (Pier 1S & 3S) under full-scale vessel impact. To accomplish these objectives, the following tasks were performed:

a) Insitu soil tests (SPT, CPT, DMT, PMT) were performed at Piers 1S & 3S, for which P-Y and T-Z static resistance models were developed for all soil layers.

b) A fully instrumented mini-pile, soil stress cells, pore pressure cells, and accelerometers were placed within and around the Pier 1S pile group.

c) The Mini-pile, as well as the soil stress and pore pressure devices in the vicinity of the pile cap were monitored during multiple barge impacts.

d) All of the instrumentation data was reduced; i.e. pile moments, shears and displacement along the length of the mini-pile, and the dynamic soil-pile cap resistance were found as a function of time for each impact.

e) From the mini-pile's shear distribution along its length, individual soil dynamic (i.e. static, damping, and inertia) resistance was obtained by layer.

f) FB-MultiPier and LS-Dyna time domain models/analysis were performed on Pier 1S and 3S including static (i.e. P-Y, and T-Z) damping (viscous) and inertia effects.

## FINDINGS AND CONCLUSIONS

To quantify the influence of inertia, damping and static resistance during a vessel collision, an approach and a main channel pier at St. George Island Causeway were subjected to a full-scale barge impact. The results were monitored and subsequently modeled. The following findings were identified from both the experimental and analytical work:

1. Maximum soil-structure resistance for both piers occurred at the time of maximum impact loading and not at maximum lateral displacements.
2. Significant dynamic resistance (60% to 70%) occurred from the soil and from the piles and the cap.
3. The soil-structure interaction characterized with nonlinear lateral (P-Y), axial (T-Z), and lateral dashpots predict well both the magnitude and periods of Pier 1S and 3S time history response.
4. The damping resistance acting on the face of the cap and seal could be accounted through the use of pile group interaction multipliers (0.8, 0.4, etc.).
5. The lateral nonlinear P-Y soil-pile springs exhibited both gapping and loss of stiffness with cycles of loading.
6. The static (P-Y and T-Z) and soil resistance may be obtained from conventional insitu testing (i.e., SPT, CPT, PMT, DMT).
7. The soil layer damping was obtained from either the Smith or the El Naggar viscous damping approach; however, further field-testing is warranted.

Current AASHTO bridge foundation design employs an equivalent static analysis. Analysis of the main channel pier (Pier 1S) through a static soil-structure characterization showed that Pier 1S should have undergone excessive deformations and pile failure at the maximum impact load of 900 kips. Through the use of a time domain analysis, which included both inertia and damping resistance, a maximum lateral pier translation of just 0.65" occurred. The time domain analyses (i.e., FB-MultiPier, LS-DYNA) of the soil-structure interaction provided excellent results when performed using the traditional P-Y and T-Z nonlinear soil springs (with p-y multipliers) with viscous lateral dashpots located along the piles and pile cap.

## BENEFITS

This research suggests that the use of time domain analysis may result in a more accurate assessment of time rate dependent forces (inertia and damping) than analysis that considers only static resistance, as per the AASHTO code. This type of analysis may provide more options for the design of bridges (new and retrofitted) subject to vessel impacts, which could prove both safer and more cost-effective.

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