Project Summary

Texas Department of Transportation

0-4650: Vessel Impact on Bridges

Background

The collapse of the Queen Isabella Causeway Bridge resulting from a vessel collision motivated this study that recognizes that vessel impact on bridges is a serious issue and that the likelihood of such accidents needs to be carefully evaluated in the design and evaluation of any bridge that spans a waterway. This project focused on revisiting the 2004 American Association of State Highway and Transportation Officials (AASHTO) Load and Resistance Factor Design (LRFD) code provisions pertaining to vessel collision analysis. The project's objectives were to re-evaluate current vessel collision analysis calculations, to create a database of information such as vessel traffic for bridges spanning waterways in Texas, and to develop software to permit probabilistic analyses that can confirm whether or not a bridge is adequately designed for acceptable risk levels.

What the Researchers Did

Regarding re-evaluation of the procedure for computing vessel impact forces in the AASHTO design code, finite-element analysis-based simulations of the impact of a loaded jumbo hopper barge with a pier were carried out using ANSYS and LS-DYNA. Two different pier prototypes were studied. Multi-linear plasticity models were used for both the concrete and the steel. Several parametric studies were carried out that considered the angle of impact, the contact height, material properties, mesh density, etc.

Regarding re-evaluation of the procedure for assessing the ultimate strength of bridges, analyses for impact loads on reinforced concrete bridge piers, with and without shear walls, were carried out using SAP 2000 and ANSYS. A truss-grid model was introduced to capture the inelastic response of shear walls in a bridge pier. Examples involving two representative bridges from Texas were presented. System-wide bridge response to impact loads was investigated. The response of a multi-column bridge pier, given the failure of a single column, was also discussed.

A database was developed based on relevant information on waterways, vessels, and bridges that span the Gulf Intracoastal Waterway (GIWW) as well as a number of other waterways. This database was integrated with the software, VIOB (Vessel Impact on Bridges), that was developed in order to make possible the large number of calculations necessary to estimate the return period associated with collapse of a bridge spanning a waterway. Making use of the assembled database on vessel traffic, the waterways, and the bridges, VIOB performs an entire bridge analysis using all of the procedures outlined in the AASHTO LRFD specifications.

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What They Found

From the vessel impact force simulation study, it was found that, depending on the event parameters (the contact point and angle of impact, for example), the AASHTO specifications could lead to either a conservative or an inadequate design. Further research is needed to arrive at a rational basis for the design guidelines that would depart from the current overly simplistic provisions concerning vessel impact force levels.

From the study of the ultimate strength of bridges subjected to vessel impact, it was found that the use of either a truss-grid model or shell elements for the wall led to similar load versus displacement responses for a range of load locations and boundary conditions. For loads applied along the length of a column away from lateral support elements, the response of an individual column controlled the ultimate lateral strength, and extensive modeling of the entire structure is not required. When impact loads were considered at or near locations of beams or walls providing lateral support for a pier, forces were distributed throughout the entire bridge pier and inelastic response spread through the structure. Then, inclusion of the bridge superstructure and adjacent bridge piers in a model had a noticeable effect on the ultimate lateral strength of the bridge systems.

The software VIOB with the integrated database consisting of key information on bridges, waterways, and vessel traffic offers a convenient platform for carrying out all the calculations associated with estimating the annual frequency of collapse of a bridge spanning a waterway. The program is easy to use, and new information can be conveniently added whenever necessary.

What This Means

The study suggests that in assessing forces involved in vessel impacts with bridge elements and in assessing the ultimate strengths of bridges, the AASHTO specifications are greatly simplified. Computational analyses carried out reveal significant differences from code provisions. It is recommended that the probability of collapse computations might need to be revisited especially because they directly influence the estimated annual frequency associated with collapse of a bridge. The availability of the software VIOB allows efficient and convenient estimation of the annual frequency of bridge collapse of any bridge spanning a waterway, and relevant data needed for these computations are integrated with the software and can be updated easily.

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