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Feasibility of Tubular Fender Units for Pier Protection Against Vessel Collision

Introduction

The potential for vessel collisions with bridges is rapidly increasing, as a larger number of heavier vessels are making more frequent trips under bridges. In the United States, rigorous design of bridges for vessel collision was first incorporated in 1991 by the *AASHTO Guide Specification and Commentary for Vessel Collision Design of Highway Bridges*, in which a model to determine vessel collision forces required for designing bridge elements was introduced. The *Guide*, of which portions have been adopted into the AASHTO LRFD Bridge Specifications, does not provide specific provisions for the design of pier protection systems. Given the high number of bridge structures in navigable waterways in Louisiana, bridge pier protection is of concern to the Louisiana Department of Transportation and Development (LADOTD), and it was desired that bridge fender systems that provide acceptable collision performance be identified.

Objective

The goal of this project was to identify existing protective systems and propose new systems that can be used to mitigate the effects of bridge/vessel collisions.

Scope

Timber piles are key components in the majority of bridge fender protection systems in the State of Louisiana. Timber piles, however, suffer from a number of drawbacks: 1) they are inadequate for medium and high energy collisions and can easily be damaged in low energy collisions; 2) they are susceptible to attacks by marine borers and have a relatively short service life; and 3) damaged piles pose disposal problems when being replaced. These disadvantages have prompted interest in finding alternative pier protection techniques that are: 1) modular; 2) easily installed or replaced; 3) suitable for retrofitting existing bridges or for use in new construction; 4) crashworthy, i.e., highly damage tolerant with good energy absorption and stiffness characteristics; and 5) durable, with low life-cycle costs.

Research Approach

A comprehensive literature review was conducted as part of the project. The survey identified existing systems in other states and countries and categorized them into six main types. A historical survey of various vessel/bridge collisions was also compiled. Based on the results of the survey, a number of alternative fender systems were identified. A new performance based design philosophy was then proposed to evaluate their protective ability.

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Assuming a Class IV, standard hopper barge (displacement = 1900 tons) as the specified design vessel, three performance levels were considered in the developed design methodology: low energy, medium energy, and high energy collisions. In the first performance level, both fender system and barge are expected to behave elastically during impact. A low energy collision is expected to occur frequently during the operating life of the fender. The fender and barge should not require any repairs after such an event. The velocity for the design barge for this performance condition is specified to be 1 knot. In the second performance level, the fender system is expected to behave elastically and does not suffer permanent damage. However, the vessel may undergo some limited inelastic deformation. A medium energy collision is expected to occur infrequently during the operating life of the fender. The fender should not require any repairs after such an event, but the vessel may require some repairs. The velocity for the design barge for this performance condition is specified to be 3 knots. In the third and most severe performance level, both fender and barge will suffer extensive damage after such a collision. It is also expected that the barge will not sink and at the same time have such diminished kinetic energy that it does not deliver a significant impact force to the bridge pier after penetrating through the protection system. A high energy collision is expected to occur rarely during the operating life of the fender. The velocity for the design barge for this performance condition is specified to be 5 knots.

The methodology used for evaluating the feasibility of pier protection systems is based upon energy balance considerations. A number of existing and newly proposed systems were evaluated using this technique, including pier mounted aluminum foam fenders, independently supported cantilevered piles and pile clusters, independently supported battered pile systems, piles in minidolphin configurations, end dolphins, pier-mounted elastic crash cushions, and pier-mounted plastic energy absorbing crash cushions.

Conclusions

Using a newly proposed multi-tiered performance-based design methodology, the performance of a number of alternative fender systems was evaluated and their suitability for bridge protection examined. The study found that cantilevered fiber reinforced polymer (FRP) piles arranged in clusters of two can provide adequate sideways protection for the low and medium energy performance levels. However, they cannot provide protection for head-on collisions for any of the performance levels. For such an application, pier mounted, inelastic energy absorbing fenders were shown to be suitable for absorbing crash energy and reducing impact forces to acceptable levels. The proposed plastic-energy-absorbing fender systems can be tailored to achieve a wide range of applicability and therefore have great potential for widespread usage. However, additional research is needed to provide proof-of-concept and to engineer a viable and marketable product. It is envisioned that both experimental and computational research will be needed to develop and optimize a system that could be widely adopted in Louisiana and across the country.

Benefits

The proposed vessel collision protection system comprised of fiber-reinforced polymer (FRP) composites for sideways protection combined with metal crash cushions for head-on protection is a cost effective alternative to traditional timber piles. A successful implementation of this project will have far reaching safety benefits to Louisiana and other states. In particular, the use of high performance FRP piles and metallic crash cushions will reduce the hazard associated with vessel collision with bridge piers and therefore improve the safety of bridges that cross navigable waterways in Louisiana and across the nation.