PRESS RELEASE

FENDER/DOLPHIN SYSTEMS FOR ROUTE 5 BRIDGE OVER CHICKAHOMINY RIVER

2010 ACEC/MD Engineering Excellence Honor Award

This project involved a new replacement bridge carrying Route 5 over the Chickahominy River, which is both a tidal and navigable waterway. This major bridge has 21 spans totaling 2,550 feet and is considered 'critical' from a security standpoint. Given that many serious bridge failures have historically been caused by marine vessel collision, the role of ***Alvi Associates*** was to first perform a comprehensive vessel collision study and then design fender/dolphin systems. The fender system consists of two concrete fenders which guide vessels through the high-level main span, along with providing some collision protection to the bridge. The dolphin system consists of four circular concrete dolphins strategically placed near the piers of the main span, with one dolphin upstream and downstream of each pier, to sacrificially protect the piers against collision by errant vessels, including large vessels which manage to break through the fenders.

Complexity

We juggled an unusually large number of issues which made the project quite complex:

- Our vessel collision study began with extensive research to collect data from many sources including the Virginia DOT (VDOT), Coast Guard, NOAA, Corps of Engineers, USGS, James City County, and several private organizations. This data was used to investigate frequency and speed of past and future vessel traffic through the bridge, and the risk of future tropical storms, hurricanes, and storm surges. Detailed analysis was then performed to determine the probabilistic risk of vessel collision with the bridge piers, as well as forces on the piers in the event of collision. The study was documented by a 50-page report.
- The fender/dolphin systems use a total of 106 concrete piles, each 100 feet long and installed in water depths up to 46 feet.
- Structural design usually involves sizing members to resist computed forces. By contrast, the fender/dolphin systems were designed using energy principles, such that vessels will be brought to a halt by absorbing the kinetic energy of their motion and converting it into deformation of the fenders and dolphins. This required modeling two types of nonlinearities: the nonlinear bending behavior of the piles as they progressively fail, and the nonlinear soil-structure interaction between the river bed material and the piles.
- The construction of the new fenders and dolphins had to be coordinated with removal of the existing bridge, removal of the existing fenders, construction of the new bridge, and avoiding existing piles, all while maintaining both bridge traffic and vessel traffic. This required choreographing a rather intricate construction sequence involving *ten* stages.

Original or Innovative Application of New or Existing Techniques

Vessel collision study normally considers the scenario of a vessel going astray while attempting to safely pass through a bridge, but this project added the scenario of the bridge being impacted by a vessel from the James River, which is a major navigable waterway downstream of the bridge. This required a detailed study of navigable channel locations and depths, tidal ranges, normal river currents, and influences of tropical storms, hurricanes, and storm surges. For this unique study, we developed an original approach which goes well beyond the framework of the applicable AASHTO guide specification.

Also, for the fenders/dolphins, we used a partially-prestressed concrete design which is a 'best of both worlds' hybrid of conventional reinforced and prestressed concrete design. The basic idea is to use regular rebar for ductility and energy absorption capacity, while using prestressing steel for strength and crack control (for durability). Partially-prestressed concrete is not covered by the applicable AASHTO design code, and even the relevant ACI committee covers it only conceptually. We therefore pioneered custom design criteria by working from fundamental principles of structural mechanics.

Social, Economic, and Sustainable Design Considerations

Given that this is a major security-critical bridge, keeping it in service is essential. To address this, our study provides a thorough assessment of vessel collision risks, and our fender/dolphin design cost-effectively protects the bridge by using a model sophisticated enough to accurately represent the complex behavior of the fenders and dolphins during vessel collision.

While our primary mission was to protect the bridge, the needs of the many recreational boaters in the area weren't forgotten. Specifically, we incorporated rubber fenders – not too hard and not too soft – into the primary concrete fenders, so that sailboats and other small boats colliding with the fenders will be gently redirected without significant damage to either the boats or the fenders.

Also, the fenders and dolphins were designed with all-concrete construction to minimize future maintenance needs, costs, and the environmental impacts associated with working in the waterway. For this purpose, low-permeability concrete was used for cast-in-place elements and 8,000-psi precast concrete was used for the piles.

Exceeding Client/Owner Needs

The bridge itself was designed in-house by VDOT and we coordinated directly with them. In their performance review, VDOT noted that we exceeded their expectations with respect to 'cooperation with VDOT', 'attitude toward work', 'initiation of work in a timely manner' (all schedules were met), and 'diligent' consultation during construction (usually with same-day response). Moreover, construction of the fenders/dolphins went smoothly, with 'no negative feedback' from the field.

Future Value to the Engineering Profession

Addressing the collision risk posed by marine vessels is an important element in ensuring the safe and reliable functioning of US bridge infrastructure. The innovative and cost-effective fender/dolphin systems designed for this project can hopefully serve as a model for other bridges needing such protection, including many of the existing US bridges which span navigable waterways but are currently unprotected.