FHWA-HEP-14-053

U.S. Department of Transportation
Federal Highway Administration

U.S. DOT Gulf Coast Study, Phase 2

Engineering Case Study 4: Bridge Abutment Exposure to Storm Surge

This is one of 11 engineering case studies conducted under the Gulf Coast, Phase 2 Project. This case study focused on the vulnerability of the western abutment of US 90/98 Tensaw-Spanish River Bridge to storm surge.

Description of the Site and Facility

The US 90/98 Tensaw-Spanish River Bridge, also studied in Case Study #3, serves as an alternative to the main I-10 crossing over Mobile Bay and as an access road to local commercial businesses. This case study evaluates whether the western bridge abutment is vulnerable to scour during potential storm surges.

The bridge abutments are stub abutments with riprap capped earthen fill providing a spill through frontage. The abutments are armored against scour by three different protective features that work in unison:

- Willow mattress[1]
- Timber and concrete bulkhead
- Stone riprap[2]

These features enable the abutment to be protected against surges that it might not be able to withstand on its own. The three components work together as a protective system, each contributing their own measure of protection. If one of these components does not perform as anticipated, then the entire protective system is weakened.

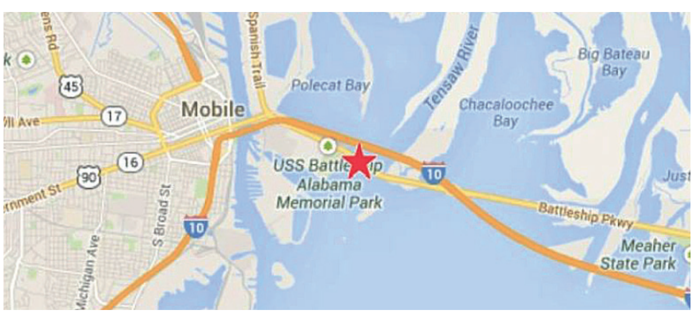

Figure 1: Location of the US 90/98 Tensaw-Spanish River Bridge within the Mobile Metropolitan Area

Climate Stressors and Scenarios Evaluated and Impacts on the Facility

This case study focused on the combined effects of storm surge and sea level rise. To assess a range of possible storm surge impacts, this analysis considered three storm scenarios, including:

- Hurricane Katrina Base Case Scenario: This scenario represents the surge conditions that actually occurred in Mobile during Hurricane Katrina.
- Hurricane Katrina Shifted Scenario: This scenario estimates the surge levels that could have occurred if Hurricane Katrina's path was shifted east to make landfall directly in Mobile.
- Hurricane Katrina Shifted + Intensified + Sea Level Rise (SLR) Scenario: This scenario estimates the surge levels that would occur if Hurricane Katrina made landfill directly on Mobile, intensified with stronger winds, and came on top of 2.5 feet (0.8 meters) of sea level rise.

In the absence of protective features, all three of the coastal storm surge scenarios result in scour depths that exceed the constructed depth of the abutment foundation, indicating that the west abutment would be prone to failure under these storm conditions if not protected. In the more extreme storm surge scenarios, the lower cord of the bridge deck is also submerged, which lowers the predicted abutment scour but could result in damage to the approach roadway and loss of service during the surge and the immediate aftermath (due to clean-up).

1 A willow mattress is an interwoven series of willow branch cuttings, joined to form a contiguous semi-rigid mattress.
2 Riprap consists of loose stone placed in a manner to provide erosion protection or armoring over a soil area.

Next, the effectiveness of the existing protective features in preventing scour was analyzed as follows:

- Willow mattress pad: The peak storm velocities were compared to the estimated permissible velocity for the willow mattress; the mattress pad is believed to be stable under all of the storm surge scenarios.
- Bulkhead: Using the same analysis as for the abutment, the bulkhead depths were determined to be insufficient to protect the abutment against the peak scour conditions; however, the bulkhead is protected by the willow mattress pad and was therefore considered to be stable under storm conditions.
- Riprap: The riprap was evaluated using guidance from the FHWA HEC-23 publication. Using the Isbash equation (which calculates the appropriate size riprap for protection), it was determined that the current riprap will resist abutment scour. Additionally, the base of the riprap is protected from wave forces by the bulkhead.

Overall, while the abutment itself is not designed to be stable under storm scour conditions, the protection components of riprap, bulkhead, and willow mattress pad are all stable, resulting in an abutment system that is stable under all evaluated storm events.

Identification and Evaluation of Adaptation Options

Because the overall abutment system was found to be stable under all storm scenarios, adaptation of this asset may not be necessary. However, the following adaptive design options may be considered for other abutments:

- Reconstruction of the protective bulkhead with increased depth, more sustainable material, and appropriately sized riprap coverage
- Realign flow vectors to be parallel to abutments through use of guidebanks or other measures
- Armor the bridge opening with riprap, a concrete revetment, or bulkhead/retaining walls
- Widen, lengthen, or shift the bridge
- Control drainage from the embankment and roadway to minimize erosion

Figure 2: Aerial Image of the US 90/98 Tensaw-Spanish River Bridge

Factors that will influence the selection of adaptation measures include:

- Redundancy: Abutment failures can take a long time to repair, resulting in road closure or reduced capacity. Adaptive measures therefore may take a higher priority on important roadways for which there is not an alternate route.
- Constructability: Retrofits to bridge foundations could result in the temporary closure of a structure. Scour countermeasure work can present constructability issues due to limited clearance under the bridge.
- Durability and maintenance: The durability and maintenance of scour countermeasures, especially in light of expected surge, is a key criterion in the design of such measures.
- Environmental issues: The use of scour countermeasures or construction activities could have negative impacts on the environment, including changes to the shoreline/streambank composition.
- Aesthetics and recreational use: The use of a context sensitive treatment that does not limit the usage of the shoreline or create an eyesore, should be considered.

Potential Course of Action

Based on the ability of the existing protection measures to provide adequate scour protection under all future storm scenarios, no adaptation measures are recommended at this time. This conclusion should be re-evaluated if updated climate projections project more severe surge conditions at the facility.

It is important to note that the extent to which the current protective features will provide long-term protection against scour is greatly influenced by their repair conditions. It is therefore recommended that the abutments should be monitored and undergo periodic inspections (including inspections after significant storm events) to assess the condition of each protection element and recommend any needed repairs.

Lessons Learned

A combination of engineering protection options can be used to effectively prevent scour from storm surges. Protective features like riprap and willow mats play an important role in the ability of an asset to withstand surge—even if the asset itself appears to be on dry ground. However, the effectiveness of the protective features is undermined if the features fall into poor condition. It is therefore vital that inspectors look at the whole picture when inspecting assets, to ensure these protective features stay in good condition.

Rooting future scenarios in the experience of a single historical weather event, and then altering characteristics to reflect possible future permutations, has the benefit of providing very relatable results to local stakeholders, especially if a severe storm event occurred recently.

Current methodologies for estimating abutment scour are very conservative, especially for locations with adequately sized and installed protective features. Abutment scour analysis procedures should be developed to more accurately predict and characterize abutment scour.

Figure 4: Example of typical timber bulkhead protection at a highway bridge abutment

Figure 3: Representative willow mattress pad (assemble prior to submergence

For More Information

Resources:

Gulf Coast Study:
[Engineering Assessments of Climate Change Impacts and Adaptation Measures]

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