LOUISIANA TRANSPORTATION RESEARCH CENTER
LTRC

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State Project No. 30000118 / LTRC Project No. 10-4ST

Development of Wave and Surge Atlas for the Design and Protection of Coastal Bridges in South Louisiana

INTRODUCTION

The failures of highway bridges on the Gulf Coast seen in the aftermath of Hurricane Katrina in 2005 were unprecedented. In the past four decades, wind waves accompanied by high surges from hurricanes have damaged a number of coastal bridges along the north coast of the Gulf of Mexico. Hurricane Camille in 1969 caused damage to bridges across Bay St. Louis and Biloxi Bay in Mississippi. Katrina damaged the same bridges rebuilt after Camille. In 1979, Hurricane Frederic destroyed the bridge connecting the mainland to Dauphin Island, a barrier island near the entrance of Mobile Bay, Alabama. In the 2004 hurricane season, Hurricane Ivan destroyed the bridge on I-10 over Escambia Bay in Florida.

There are a large number of coastal bridges in South Louisiana. This study addresses several aspects of evaluation of these bridges including: how many bridges are vulnerable to the impact of hurricanes; determination of the design wave and surge conditions at those bridge locations; and calculation of the wave forces on the bridge superstructures. The storm surge elevation, wave height, and wave period are the three most important meteorological and oceanographic (met/ocean) parameters needed to calculate wave forces according to AASHTO's Guide Specification for Bridges Vulnerable to Coastal Storms. This information is currently not available for South Louisiana's coastal waters. To address these concerns, LTRC funded this project to develop the design surge elevations and wave heights for South Louisiana, and present the data in a Geographical Information System (GIS) database.

OBJECTIVE

The purpose of this study was to (1) establish 100-year design surge/wave data for Louisiana coastal waters and to present the results in a Surge/Wave GIS Database (Storm Surge and Wave Atlas) and (2) identify DOTD bridges vulnerable to this type of loading from the surge/wave data and bridge information.

These objectives provide the DOTD with a list of their coastal bridges vulnerable to design storm surge and wave conditions. The amount the design surge/wave load exceeds the resistive forces (span dead weight) is provided for the most vulnerable span on each bridge examined in the study. The storm surge and wave atlas developed in this study will provide the surge/wave information needed for analyzing storm surge and wave loading on future DOTD coastal bridges, roadways, and other structures.

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METHODOLOGY

Development of the Storm Surge and Wave Atlas and the design conditions at each of the project bridges required development the 100-year design surge/wave data. To develop the 100-year design surge/wave data, the study conducted a Level III analysis—as outlined in the AASHTO specification Guide Specifications for Bridges Vulnerable to Coastal Storms—for South Louisiana coastal waters. This involved developing and calibrating an ADCIRC+SWAN model to hindcast the most severe tropical storms and hurricanes that have affected Louisiana's coastal waters. Extreme value analysis of the hindcasted storms provided the 100-year surge/wave data. The results, presented in the Storm Surge and Wave Atlas with a public domain GIS reader, provided the input for evaluating bridge vulnerability. The proprietary computer model, Physics Based Model (PBM), developed by OEA/INTERA computed the surge/wave loads on the bridges examined in this study. The vulnerability index, which is the calculated forces/moments with the appropriate load factors divided by the resistive forces/moments (superstructure dead weight), provides the means for determining the bridge's vulnerability. Bridges with vulnerability indices equal to or greater than one were classified as vulnerable.

CONCLUSIONS

Results of this study provide the DOTD with design surge/wave data throughout southern Louisiana. That data provided the input to identify DOTD's vulnerable coastal bridges and develop the Storm Surge and Wave Atlas. Of the 64 bridges examined, this study identified 17 bridges as potentially vulnerable to hurricane wave and surge generated loading on the bridge superstructures.

RECOMMENDATIONS

For those bridges identified as vulnerable, retrofit options include adding constraints and providing venting to reduce the volume of trapped air between girders. In many cases, particularly for older bridges, the more appropriate plan of action is eventual replacement. Implementation of countermeasures or retrofit options are at the discretion of the DOTD and beyond the scope of this study.

For future bridges, the Storm Surge and Wave Atlas provides hurricane storm surge and wave design parameters. This data aids the Department in setting low chord elevations to prevent wave impacts on bridge superstructures or in identifying bridges requiring incorporation of wave loading into design.

The current Atlas contains surge and wave information with a 1% chance of occurrence each year (100-year return interval). This information is useful for computing wave loads on bridge superstructures. There are, however, many issues encountered by DOTD engineers that require other frequency meteorological/oceanographic information (e.g., 10-, 25-, 50-year return interval values). For instance, a temporary facility (a detour bridge) may be designed based on a 5-year return interval (20% chance of occurrence each year). Bridges whose service life is approaching their design life may be retrofitted based on a return interval different from 100-year return interval. Therefore, the research team recommends a Phase-II study where surge and wave information for different returned intervals, as well as corresponding forces on coastal bridges, be developed and provided in separate GIS databases.

Figure 1
Interstate 10 damage following the passing of Hurricane Ivan

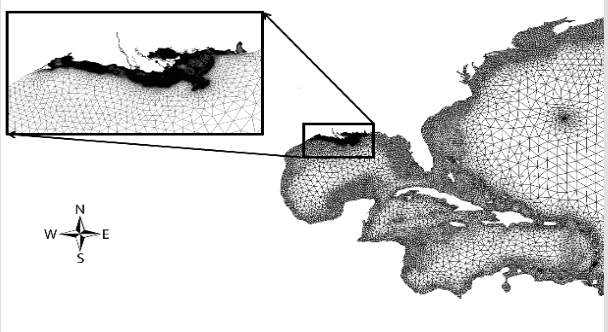

Figure 2
ADCIRC/SWAN mesh model domain with inset showing detail of coastal Louisiana