Design Guides for Bridges Vulnerable to Coastal Storms

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AASHTO
Guide Specifications for Bridges Vulnerable to Coastal Storms

Modjeski & Masters Inc. – Prime
OEA, Inc. – Sub.
Outline

- Background
- AASHTO Specs
  - Design Met/Ocean Parameters
    - Levels I, II and III
  - Force/Moment Computations
    - Low frequency (wave frequency)
    - High frequency (slamming)
  - FDOT bridge vulnerability methodology
Background

- Forces and moments on bridge superstructures created by elevated water levels and waves
Background

- Problem can be divided into two components
  - Design water elevation and wave parameters
  - Computing surge/wave forces and moments
- AASHTO specs address both issues
Background

- Bridge Vulnerability
  - When applied design forces and moments exceed resistive capacity due to dead weight and tie-downs bridge is vulnerable
Storm Surge and Waves

- Maximum loading conditions
  - Maximum water elevation and associated waves
  - Maximum wave heights and associated water elevation
- AASHTO Specs
  - Level I
  - Level II
  - Level III
Level I Met/Ocean Analysis

- Uses existing data and empirical equations
  - 100-year storm surge – usually FEMA
  - USACOE empirical equations for computing wave parameters (heights and periods)
- Usually yields conservative results
  - Maximum water elevations and wave heights
  - Phasing not taken into consideration
- Used primarily for screening
OEA conducted Pilot Study for Florida DOT
- Performed Levels I, II and III met/ocean analyses
- FDOT District 7 – Tampa, Saint Petersburg area
- Analyzed 52 bridges
FDOT Pilot Study Area
D7 Bridges Investigated
Level I Potentially Vulnerable Bridges

34 out of 52 determined to be potentially vulnerable
Level II Met/Ocean Analysis

- More effort required than for Level I
- Slightly more accurate than Level I
- Some computer modeling – usually wave
Level II Potentially Vulnerable Bridges

32 out of 52 determined to be potentially vulnerable
Level III Met/Ocean Analysis

- Increase in effort required over Levels I and II
- Significant increase in accuracy
- Extensive storm surge and wave modeling
- Extreme value analyses
- Produces substantial useful information (beyond that needed for surge/wave loading)
Level III Met/Ocean Analysis

- Florida Pilot Study Level III Analysis
  - Hindcasted 30 actual storms that had impacted the study area (plus ~ 60 variations of these storms)
  - Performed extremal analyses to obtain design conditions
9 out of 52 determined to be potentially vulnerable
Outlines methodology for Levels I, II and III met/ocean analyses

Presents equations for computing:

- Maximum vertical force and associated horizontal force and overturning moment
- Maximum horizontal force and associated vertical force and overturning moment
- Horizontal forces on substructure
Surge/Wave-Induced Loads

- Predictive methods in AASHTO codes developed by FDOT and FHWA/AASHTO funded projects
  - Sheppard and his graduate student (Marin) at the University of Florida (with FDOT funding)
  - OEA, Inc. (with FHWA/AASHTO funding)
Storm Surge/Wave Forces

**Horizontal Forces**

\[ F_H = F_{\text{Drag}} + F_{\text{Inertia}} + F_{\text{CAM}} + F_{\text{Slamming}} \]

**Vertical Forces**

\[ F_V = F_{\text{Buoyancy}} + F_{\text{Drag}} + F_{\text{Inertia}} + F_{\text{CAM}} + F_{\text{Slamming}} \]
Girder Span Tests
Equations developed at the University of Florida
Proprietary computer program (PBM) developed by OEA to evaluate equations
PBM used to generate force and moment data for wide range of structure and met/ocean conditions
OEA used PBM data to develop parametric equations for AASHTO spec
Required input for equations:
- Superstructure type, dimensions, elevation
- Design water elevation, wave height and period

Output:
- Maximum vertical force and associated horizontal force and overturning moment
- Maximum horizontal force and associated vertical force and overturning moment
- Maximum overturning moment and associated vertical and horizontal forces
Vulnerable Bridges

- FDOT is currently using the following criterion:
  - Classify bridges as “Extremely Critical”, “Critical”, or “Non-Critical”
  - Extremely Critical – Design to withstand surge/wave forces to the strength limit state (1.75 load factor)
  - Critical – Design to withstand surge/wave forces to the extreme event limit state (no load factor)
Storm surge and wave loading on bridge superstructures have destroyed a number of important bridges during the last decade, e.g.

- I10-Escambia Bay Bridge – Pensacola, FL
- US90 Biloxi Bay Bridge – Biloxi, MS
- US90 Saint Louis Bay Bridge – Bay Saint Louis, MS
- I10-Lake Pontchartrain Bridge – New Orleans, LA

AASHTO *Guide Specifications for Bridges Vulnerable to Coastal Storms* provide guidelines for how to obtain met/ocean design conditions and the resulting forces and moments.
Summary

- FDOT conducted Pilot Study where all three levels of met/ocean analyses were performed
  - Level I analysis is good for screening but, in general, conservative
  - Level II analysis more accurate than Level I but still conservative
  - Level III accurate and yields significant useful hydraulic information in addition to that needed for surge/wave loading
Questions/Comments?