Florida Department of Transportation

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TEMPORARY DESIGN BULLETIN C09-08

ROADWAY DESIGN BULLETIN 09-07

DATE: September 8, 2009

TO: District Directors of Production, District Design Engineers, District Structures Design Engineers, District Construction Engineers, District Project Development Engineers, District Drainage Design Engineers

FROM: Robert Robertson, P. E., State Structures Design Engineer
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SUBJECT: Wave Forces on Bridges- Implementation of *AASHTO Guide Specifications for Bridges Vulnerable to Coastal Storms*

For bridges spanning waters subject to coastal storms, the *AASHTO Guide Specifications for Bridges Vulnerable to Coastal Storms* requires the superstructure to have a minimum vertical clearance of one foot above the 100 year design wave crest elevation. If this clearance, termed the "wave crest clearance", is not met, the bridge superstructure must be designed to resist storm wave forces. This Temporary Design Bulletin implements the design process for bridges vulnerable to coastal storm wave forces.

REQUIREMENTS

I. Add the following requirement to Section 4.6.1 (Vertical Clearance) of *Drainage Manual:*

3. For coastal bridges, the vertical clearance of the superstructure shall be a minimum of 1 ft. above the 100-year design wave crest elevation including the storm surge elevation and wind setup. For bridge designs where this criteria cannot practically be met, see Section 4.9.5.

II. Add the following Sections to the *Drainage Manual:*

4.9.5 Wave and Current Forces on Coastal Bridges

Where coastal bridges are not elevated at least 1 ft. above the design wave crest elevation (DWC), a qualified coastal engineer with experience in wave mechanics shall provide hydraulic data necessary for calculating wave forces. Wave forces shall be computed according to The Guide Specifications for Bridges Vulnerable to Coastal Storms.

4.9.5.1 Required Level of Analysis

A qualified coastal engineer shall assist in the PD&E scoping effort, especially with structures exposed to severe wave attack. Determinations, including the appropriate level of analysis, will be made as outlined in Structures Design Guidelines Section 2.5.1.

III. Add the following requirement to Section 4.11.2.3 (Category 1 and 2 Bridges) of the *Drainage Manual*:

2.1.10. Wave analysis (coastal bridges not elevated 1 ft. above the design wave crest elevation)

8.5. Wave analysis computations (coastal bridges not elevated 1 ft. above the design wave crest elevation)

IV. Add the following reference to *Structures Design Guidelines* Section I.6.B (SDG Introduction – References):

9.) Guide Specifications for Bridges Vulnerable to Coastal Storms (2008)

V. Replace *Structures Design Guidelines* Section 2.2.D with Table 2.1 “Miscellaneous Loads” currently in Section 2.5 “Miscellaneous Loads”.

VI. Delete *Structures Design Guidelines* Section 2.5 “**Miscellaneous Loads**” and replace with new Section 2.5 entitled “**Wave Loads**”.

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VII. Add the following requirement to *Structures Design Guidelines* Section 2.5 “Wave Loads”:

2.5.1 Wave Loads on Coastal Bridges When bridges vulnerable to coastal storms cannot practically meet the wave crest clearance requirement of the Drainage Manual Section 4.6.1, all relevant design information shall be submitted to the SDO to assist in the following determinations:

1.) The level of importance of a proposed bridge (“Extremely Critical”, “Critical”, or “Non-Critical”; See *Commentary* below)
2.) The design strategy and the associated performance objective (“Service Immediate” or “Repairable Damage”; See ***AASHTO Guide Specifications for Bridges Vulnerable to Coastal Storms*** Article 5.1)
3.) The appropriate level of analysis (Level I, II, or III; See ***AASHTO Guide Specifications for Bridges Vulnerable to Coastal Storms*** Article 6.2)

The above determinations will be made by the SDO in consultation with the DSDO, Traffic Engineer, Environmental Engineer, Hydraulic Engineer, and/or Coastal Engineer and will be included in the PD & E documents. As a minimum, the items listed below will be considered in the determinations:

- Age and condition of existing bridge structure and the feasibility/cost of retrofitting to resist wave forces (if applicable)
- Proposed bridge location and elevation alternatives (elevation relative to the design wave crest)
- Estimated cost of elevating the superstructure above the “wave crest clearance” (1 ft above the design wave crest), and/or the justification of why it cannot be done
- Affect of varying wave loading on construction costs (due to location and/or height adjustments)
- Existing and projected traffic volumes
- Route impacts on local residents and businesses
- Availability and length of detours
- Evacuation/emergency response routes
- Duration/difficulty/cost of bridge damage repair or replacement
- Other safety and economic impacts due the loss of the structure

Except where bridges satisfy the “wave crest clearance” or are deemed “Non-Critical”, the structures designer shall calculate and apply wave forces according to the ***AASHTO Guide Specifications for Bridges Vulnerable to Coastal Storms*** using the determinations defined above along with the necessary hydraulic data provided by the coastal engineer.

Commentary: Selecting a design strategy will depend on the importance/criticality of the bridge considering the consequences of bridge damage caused by wave forces. If a bridge is deemed “Extremely Critical”, it would typically be designed to resist wave forces at the Strength Limit State to the “Service Immediate” performance level. If a bridge is deemed “Critical”, it would generally be designed to resist the wave forces at the Extreme Event Limit State to a “Repairable Damage” performance level. Bridges that are deemed “Non-Critical” will not be evaluated for wave forces.

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COMMENTARY

Design wave forces acting on a bridge superstructure are typically large, so bridges designed to resist these wave forces are more costly. Accordingly, it is important to raise the bridge superstructure one foot above the 100-year design wave crest, which includes the storm surge elevation and wind setup. This clearance is also termed the “wave crest clearance”. Raising the superstructure above the “wave crest clearance” can prevent large wave forces from impacting the fascia of the superstructure and reduce overall bridge costs. It should be noted that the economic feasibility of raising the bridge superstructure above the wave crest clearance may depend on the importance of the bridge. If raising the entire bridge superstructure above the “wave crest clearance” elevation is not viable, the designer should raise the bridge as high as feasible to reduce the superstructure’s exposure to wave forces.

The levels of analysis are defined according to the *AASHTO Guide Specifications for Bridges Vulnerable to Coastal Storms*, Article 6.2. Bridge designers should perform a level of analysis appropriate for the bridge length and importance/criticality. Long and/or significant bridges should be designed using a more accurate analysis (level III) and simulation. Short and/or noncritical bridges should be designed using the quicker and more conservative (level I) analysis (As the bridge length increases, it becomes more cost effective to raise the level of analysis. This increases design costs, but increased design costs are justified by construction cost savings). The simplified level I analysis may produce extremely large design forces that are costly to resist. In these cases, level II and III analysis could provide significant savings in construction costs. The SDO will make the determination concerning whether increased efforts for level II or III analysis will be cost-effective.

Selecting a design strategy will depend on the importance/criticality of the bridge when considering the consequences of bridge damage caused by wave forces. If a bridge is deemed “Extremely Critical”, it would generally be designed to resist wave forces at the Strength Limit State to the “Service Immediate” performance level. This would be accomplished by designing the bridge to resist the wave forces with little or no damage to the bridge, so the structure could be in service immediately after the storm event (pending inspection). If a bridge is deemed “Critical”, it would typically be designed to resist the wave forces at the Extreme Event Limit State to a “Repairable Damage” performance level. Bridges that are deemed “Non-Critical” will not require evaluation for wave forces.

For all bridges spanning waters subject to coastal storms, the designer should consider simple and inexpensive measures that enhance a structure’s capacity to resist storm forces (more frequent storms of lower intensity should be considered as well). For example, the designer could place vents in all diaphragms for little or no cost. Venting all bays for all spans will reduce the effects of buoyancy forces on the structure. The designer should also consider anchoring the superstructure down to the substructure to reduce or prevent damage resulting from storms.

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BACKGROUND

On September 16, 2004, Hurricane Ivan struck the I-10 Bridge over Escambia Bay near Pensacola Florida. Wave forces from Ivan dislocated over 3,400 feet of bridge superstructures; the majority of the superstructures were dropped into the bay. One year later, the wave forces of both Hurricane Katrina and Hurricane Rita similarly damaged I-10 and US-90 coastal bridges in Louisiana.

Recent hurricane events have highlighted the need for improved design analysis methods to increase survivability of bridges vulnerable to coastal wave forces. Consequently, the Federal Highway Administration (FHWA) initiated a pooled fund contract sponsored by ten states and the FHWA resulting in the development of the *AASHTO Guide Specification for Bridges Vulnerable to Coastal Storms*. The specifications are comprehensive and embody new concepts which have not been included in previous design provisions. For more information, please see the "FOREWORD" section of the *AASHTO Guide Specification for Bridges Vulnerable to Coastal Storms*.

IMPLEMENTATION

The Requirements of this TDB are effective immediately for all new projects and current projects having not yet completed the PD & E phase of development.

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