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STRUCTURES DESIGN BULLETIN 21-02

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DATE: June 30, 2021

TO: District Directors of Transportation Operations, District Directors of Transportation Development, District Design Engineers, District Construction Engineers, District Consultant Project Management Engineers, District Structures Design Engineers, District Maintenance Engineers, District Program Management Engineers, District Materials Engineers, Structures Manual Holders

FROM: Robert V. Robertson, P.E., State Structures Design Engineer

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SUBJECT: Splash Zone Definition and Introduction of Stainless Steel Strands for Pretensioned Concrete Beams

This Bulletin expands the definition of the splash zone and introduces stainless steel strands in the ***Structures Design Guidelines*** (***SDG***) for the design of pretensioned concrete beams.

REQUIREMENTS

1. Add the following as the second paragraph of ***SDG*** 1.4.3:

   The splash zone is defined as the vertical distance from 4-feet below MLW to 12-feet above MHW and/or areas subject to wetting by personal watercraft (e.g., jet skis) or other activities and features.

   Commentary: Personal watercraft often have a visibility spout as a safety feature, shooting a pressurized stream of water vertically into the air making them more visible to operators of larger watercraft. Several bridges have experienced significant corrosion due to personal watercraft spraying chloride water onto the underside of the bridge.

2. Replace ***SDG*** 1.4.3.C with the following:

   C. Corrosion Protection: Structural components located in Moderately or Extremely Aggressive environments utilize Class IV, V, V (Special), VI or VII Concrete. These concrete classes require the use of highly reactive pozzolans and/or cement type to reduce permeability. Specify the use of highly reactive pozzolans as shown in Table 1.4.3-3.

   The use of other corrosion protection measures to enhance durability must be consistent with the strategies outlined in Table 1.4.3-3. The Engineer of Record may request additional measures to be approved by the State Materials Office and the District Structures Design Engineer. Technical Special Provisions may be required for their implementation.

Modification for Non-Conventional Projects:
Delete the second paragraph of ***SDG*** 1.4.3.C.

Table 1.4.3-3 Corrosion Protection of Concrete Components

Location/Environment	Component	Additive
Superstructure in Extremely Aggressive Marine Environment	Pretensioned concrete beams and other components located within the splash zone	Coordinate with the State Materials Office and the DSDE for guidance on design mix requirements, cover and alternative reinforcing materials. See ***SDG*** 4.3.1.A.
	Decks exposed to chloride water spilling from trailered boats due to nearby ramps or beach access	
Substructure in Extremely Aggressive Marine Environment	Piles of pile bents with carbon or stainless steel strand, spirals and/or reinforcing[1]	Highly reactive pozzolans required
	Retaining walls, including MSE walls[2] located within the splash zone and within 50-feet of the shoreline	
	Substructure elements, excluding footings, located within the splash zone	
	Drilled shafts	Highly reactive pozzolans not required
Substructure in Extremely Aggressive Environments due to pH less than 5	Piles of pile bents	Highly reactive pozzolans required
	Retaining walls, including MSE walls[2] located in the water and within 50-feet of the high waterline	
	Substructure elements, located in soil or water with low pH	
Moderately Aggressive Environments	Any component with stainless steel strand or reinforcing	Highly reactive pozzolans not required

1. See ***Standard Plans Index*** 455-001 and 455-101 for more detail on corrosion protection of piles.
2. See ***Standard Plans Index*** 548-020 “FDOT MSE RETAINING WALL CLASSIFICATION TABLE” for more detail on corrosion protection of MSE walls.

Modification for Non-Conventional Projects:
Delete the entire first row of ***SDG*** Table 1.4.3-3 (Superstructure in Extremely Aggressive Marine Environment) and see the RFP for requirements.

3. Replace ***SDG*** 4.3.1.A with the following:

    A. Prestressing strands

    1. ASTM A416, Grade 270, low-relaxation strands are the standard strand type used for the design of pretensioned beams. Do not use stress-relieved strands. Straight-strand configurations are preferred over draped strand configurations.

        Commentary: Draped strand designs are usually more efficient and have fewer issues with cracking at the beams ends due to the distribution of the prestress force over the height of the beam end. However, straight strand designs have been standard practice in Florida for decades. There are worker safety concerns with anchoring the hold-down devices, and non-standardized drape points require precasters to drill multiple holes in their casting beds for anchorage hold-down points.

    2. For pretensioned concrete beams located within the splash zone, evaluate the use of CFRP and stainless steel prestressing strands. See ***SDG*** 1.4 for definition of splash zone. Coordinate with the District Structures Design Engineer and the State Materials Office for guidance.

Modification for Non-Conventional Projects:
Delete ***SDG*** 4.3.1.A.2 and see the RFP for requirements.

    3. For CFRP strands, see ***Volume 4 – Fiber Reinforced Polymer Guidelines*** for design requirements.

4. For stainless steel strands, use the following design requirements and guidance:
   a. Use ASTM A1114, Grade 240, low-relaxation, stainless steel prestressing strands for the design of pretensioned beams. Use only straight strand configurations.
   b. Use materials for mild reinforcing and other embedded items that are compatible with stainless steel. Do not used mild reinforcing or other embedded items made of CFRP or carbon steel.

   Commentary: Grade 75 stainless steel reinforcing is the preferred compatible material for design efficiency and simplicity in construction. Glass & basalt FRP reinforcing are also compatible with stainless steel. CFRP and carbon steel reinforcing are not compatible and will experience accelerated corrosion due to electrical contact with stainless steel.

   c. Use the following design values:
      i. Resistance factor φ of 0.75 for flexure. Include this value on the Load Rating Summary Sheet.
      ii. Maximum steel stress immediately prior to transfer (f_{pbt}) of $0.65f_{pu}$.
   d. Use equilibrium and strain compatibility for design as follows:
      i. In the absence of a more exact concrete stress distribution, use the stress distribution from the ***AASHTO Guide Specification for the Design of Concrete Bridge Beams Prestressed with CFRP Systems***.
      ii. In the absence of the manufacturer's material properties, the following stress-strain relationship for the stainless steel strand can be used:

$$f_p = E_{ps} \cdot \varepsilon_p \left[0.06 + \frac{1 - 0.06}{\left[1 + \left(101 \cdot \varepsilon_p\right)^{6.45}\right]^{\frac{1}{6.45}}} \right] \leq 240ksi$$

      where:
      E_{ps} = modulus of elasticity of prestressing strand (ksi)
      ε_p = strain in the strands (in/in)
      f_p = stress in the strands (ksi)

      iii. The prestressing strand failure (rupture) is defined to occur when the strain in the extreme strand layer reaches the ultimate tensile strain (ε_{pu}) of 0.014.

iv. Meet the following minimum reinforcement limit for designs controlled by strand rupture:

$$\frac{c}{d} \geq \left(\frac{9.2f'_c + 0.48f_{pe} - 3.9}{1000}\right)$$

where:
c = distance from the extreme compression fiber to the neutral axis (in)
d = distance from the extreme compression fiber to the bottom layer of strands (in)
f'_c = compressive design strength of deck concrete (ksi)
f_{pe} = effective stress in prestressing steel after losses (ksi)

Commentary: The design requirements for stainless steel strands are based on results from research report FDOT BDV30-977-22.

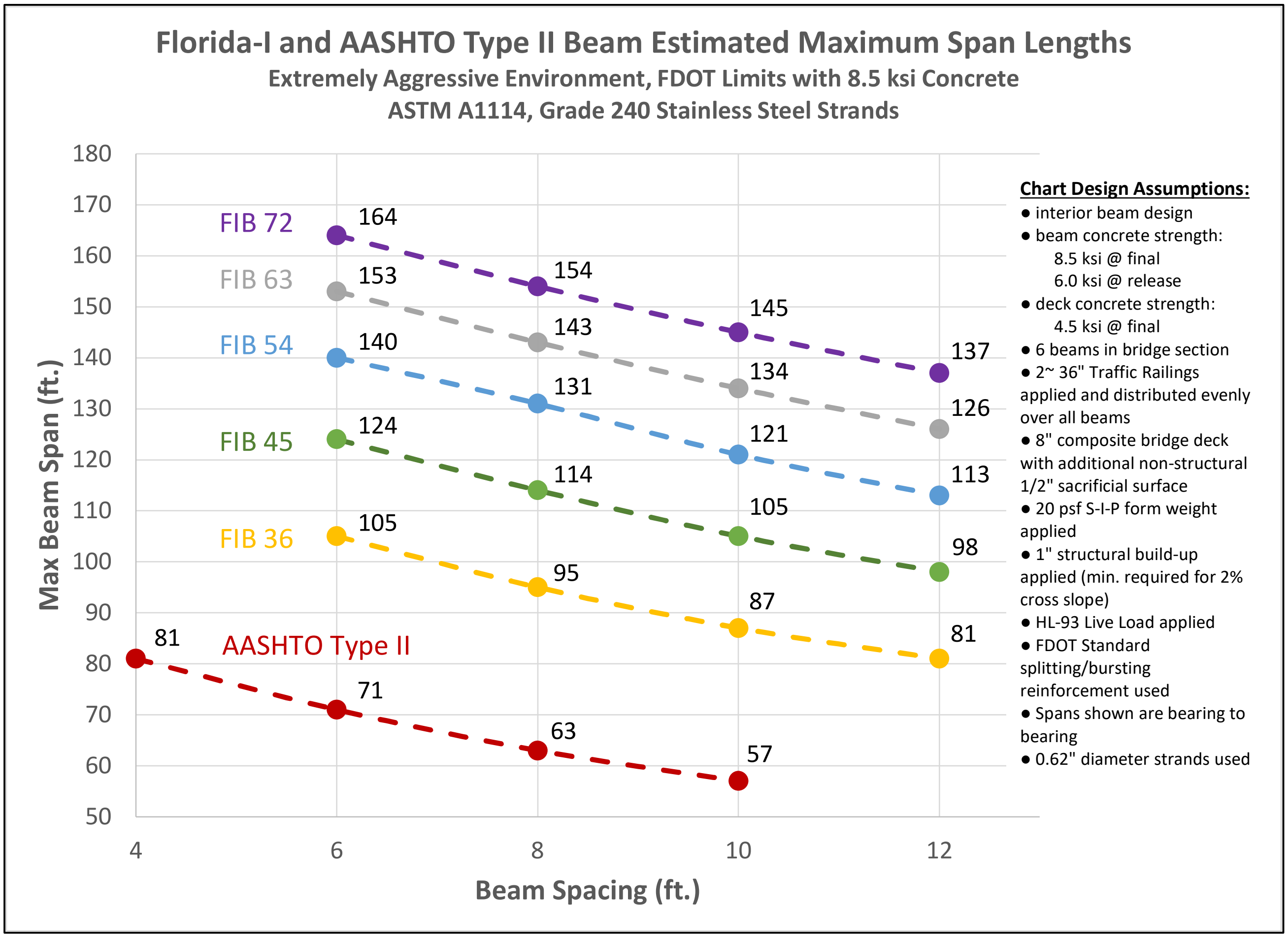
4. Add the following footnotes to ***SDG*** 9.2.2.B.2:

1 Price is based on the ability to furnish products without any conversion of casting beds and without purchasing of forms. If these conditions do not exist, add the following costs: $450,000.

2 Interpolate between given prices for intermediate width FSBs.

3 When evaluating the use of alternative reinforcing materials per ***SDG*** 4.3.1, contact at least two precasters for their input regarding cost.

5. Add the following Design Aid to the ***Instructions for Standard Plans Index 450-010 Series*** and ***Index 450-120***:



6. Replace the Table of Recommended Maximum Span Lengths in the ***Instructions for Standard Plans Index 450-450 Series*** with the following:

Table of Recommended Maximum Span Lengths (CL Bearing to CL Bearing) ASTM A416, Grade 270, Low Relaxation, Carbon Steel Strands				
Beam Type	**6" C-I-P Topping w/ Future Wearing Surface (Short Bridge)**		**6½" C-I-P Topping w/ ½" Sacrificial Thickness (Long Bridge)**	
	Beam Width		**Beam Width**	
	4'-0"	**5'-0"**	**4'-0"**	**5'-0"**
12" FSB	40'-11"	43'-11"	41'-2"	44'-5"
15" FSB	52'-11"	56'-3"	53'-3"	56'-9"
18" FSB	62'-3"	64'-4"	62'-8"	64'-10"

Table of Recommended Maximum Span Lengths (CL Bearing to CL Bearing) ASTM A1114, Grade 240, Low Relaxation, Stainless Steel Strands		
Beam Type	**Short and Long Bridge** Note: Maximum lengths are applicable to both 6” C-I-P Topping with Future Wearing Surface and 6 ½” C-I-P Topping with ½” Sacrificial Thickness	
	Beam Width	
	4'-0"	**5'-0"**
12" FSB	36'-11"	39'-9"
15" FSB	48'-5"	51'-8"
18" FSB	57'-11”	57'-11"

BACKGROUND

This bulletin introduces stainless steel strands in pretensioned concrete beams as part of the Department's on-going efforts to advance the use of innovative corrosion-resistant materials, with the intent of extending bridge service life and decreasing future maintenance costs. Bridges in Florida are commonly located along the coast in extremely aggressive marine environments. For bridges located in these environments, the deterioration of standard carbon steel materials is one of the prime causes for increased maintenance and repair costs and structurally deficient concrete superstructures.

This bulletin also addresses the following two specific sources of corrosion that the Department has encountered over the years: (1) The traditional splash zone definition used by the Department is expanded to include coastal areas subject to the frequent use of personal watercraft (e.g., jet skis). Personal watercraft often have a visibility spout as a safety feature, shooting a pressurized stream of water vertically into the air making them more visible to operators of larger watercraft. Several bridges have experienced significant corrosion due to personal watercraft spraying chloride water onto the underside of the bridge. (2) The corrosion protection provisions now address concrete decks of bridges that are near boat ramps or beach access. Trailered boats leaving these areas spill chloride water onto the bridge deck. Several concrete decks have experienced significant corrosion due to nearby boat ramps or beach access.

Various grades of stainless steel strands have been available for years, however, their mechanical properties and their behavior in primary flexural members required validation prior to implementation. Based on completed research and the recent release of ASTM 1114, stainless steel strands can now be considered for use in pretensioned concrete beams located in the splash zone of extremely aggressive marine environments, providing extended service life and increased durability.

Two research projects have been completed which evaluated stainless steel strands. The first project, FDOT BDK84-977-07, performed in collaboration with the University of South Florida and published in 2014, considered different types of stainless steel strands, evaluating their material properties and their corrosion resistance. It was concluded that Duplex High-Strength Stainless Steel (HSSS) strand Grade 2205 is the best option because of its high strength and corrosion resistance properties. Following this research project, the Duplex HSSS strand Grade 2205 was implemented for use in square prestressed concrete piles. The second research project, FDOT BDV30-977-22, performed in collaboration with Florida State University and completed in 2020, evaluated the material properties of Duplex HSSS strand Grade 2205 and its behavior in primary flexural members. The main objectives of this research were to provide recommendations for minimum guaranteed mechanical properties of Duplex HSSS strand Grade 2205 and to provide design guidance for its use in primary flexural members.

ASTM A1114 was released in 2020, providing industry-accepted minimum guaranteed material properties. The strand material and the testing performed in research project FDOT BDV30-977-22 met the requirements of ASTM A1114. Therefore, ASTM A1114 will be added to Section 933 of the ***Standard Specifications for Road and Bridge Construction*** for the January 2022 release.

IMPLEMENTATION

These requirements are effective immediately on all design-bid-build projects at 30% plans or less. These requirements may be implemented immediately on all other design-bid-build projects at the discretion of the District.

These requirements are effective immediately on all design-build projects that have not been advertised.

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