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Florida Department of Transportation

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STRUCTURES DESIGN BULLETIN 15-06
(FHWA Approved: August 11, 2015)

DATE: August 13, 2015

TO: District Directors of Transportation Operations, District Directors of Transportation Development, District Design Engineers, District Construction Engineers, District Structures Design Engineers

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

COPIES: Brian Blanchard, Tom Byron, Tim Lattner, David Sadler, Rudy Powell, Amy Tootle, SDO Staff, Jeffrey Ger (FHWA)

SUBJECT: Prestressed Concrete I-Beam Stability and Temporary Bracing Requirements

This bulletin clarifies and updates the Department's design requirements for prestressed concrete I-beam stability and temporary bracing.

REQUIREMENTS

1. Replace ***Structures Design Guidelines*** Section 4.3.4 with the following:

4.3.4 I-Beam Stability

A. Analyze simple span prestressed concrete Florida-I Beams (FIBs) and AASHTO Type II Beams for stability for the following stages using the loads and limits shown below. Specify in the plans the bracing information listed under Plan Requirements for each stage.

1. Stage 1 – Crane release (beam sitting on bearings, no end bracing)
    a. Loads: construction active basic wind speed (***SDG*** 2.4.3)
    b. Beam Limits (For analysis methodology, see "Lateral Stability of Long Prestressed Concrete Beams – Part 2", Mast, R., **PCI Journal**, Vol. 38, No. 1, January–February 1993, pp. 70–88.):
        i. Factor of Safety Against Cracking ≥ 1.0.
        ii. Factor of Safety Against Rollover ≥ 1.5.
        iii. Factor of Safety Against Wind ($P_{max,0}$ / P_{20mph}) ≥ 4.0 using Equation 4-1.

$$P_{max,0} = 123e^{\frac{-L}{100}}\left(1+15e^{\frac{-D}{22}}\right) - 750e^{\frac{-D}{16}} - 16$$

Equation 4-1

Where:

$P_{max,0}$ = Wind pressure capacity of an unanchored prestressed beam (psf)

L = Span length (ft)

D = Beam depth (in)

P_{20mph} = Service I wind pressure during Stage 1 (psf)

c. Plan Requirements: If any of safety factors listed above are not satisfied, specify in the plans that the beam must be braced at its ends prior to crane release. If all requirements are satisfied, specify in the plans that the beam does not require bracing at its ends prior to crane release. See ***SDM*** 15.5 for plan content requirements.

2. Stage 2 - Braced Beams (no Deck Forms and end bracing required)
   a. Loads: construction inactive basic wind speed (***SDG*** 2.4.3)
   b. Beam Limits: Factor of Safety Against Cracking ≥ 1.0.
   c. Plan Requirements:
      i. Total lines of bracing. See ***SDM*** 15.5 for plan content requirements.
      ii. Minimum number of adjacent beams erected and braced together.
      iii. ***LRFD*** Strength III horizontal load at brace locations for use by the Contractor's Engineer to determine the brace forces.
3. Stage 3 – Deck Casting
   a. Loads: construction active basic wind speed (***SDG*** 2.4.3) and construction loads (***SDG*** 2.13).
   b. Beam Limits:
      i. Principal stresses at midspan ≤ 0.6 ***LRFD*** Stress Limits after losses (***LRFD*** Table 5.9.4.2.1-1).
      ii. Deck overhang deflection at the coping line due to beam rotation ≤ ¼" (assume the deck overhang formwork is rigid).
   c. Plan Requirements:
      i. Total lines of bracing (must be ≥ Stage 2). See ***SDM*** 15.5 for plan content requirements.
      ii. ***LRFD*** Strength I overturning moment(s) at brace locations for use by the Contractor's Engineer to determine the brace forces.

B. The following are minimum bracing requirements for ***Design Standards*** Index 20000 Series Florida-I Beams and AASHTO Type II Beams:

1. Stage 1: all beams 175 feet in length and greater shall be braced at their ends prior to crane release.

2. Stage 2: In addition to end bracing, intermediate bracing shall be provided as follows:
    a. AASHTO Type II, FIB 63 and FIB 72 – mid-span bracing
    b. FIB 78 – quarter point bracing
    c. FIB 84 and 96 - quarter point bracing and 3 beams erected and braced together within 24 hours.
3. Stage 3: For beams with deck overhangs ≤ ½ beam spacing, intermediate bracing shall be provided as follows :
    a. For deck overhangs ≤ 3 feet, use of Stage 2 bracing.
    b. For 3 feet < deck overhangs ≤ 3.75 feet, the greater of Stage 2 bracing or mid-span bracing.
    c. For 3.75 feet < deck overhangs ≤ 4.5 feet, use quarter point bracing.
    d. For deck overhangs > 4.5 feet, develop project specific requirements.

Assumptions:

1. Simple span beams.
2. Beam camber ≤ 6 inches.
3. ***Design Standards*** Index 20510 Composite Elastomeric Bearing Pads oriented square with the ends of the beam.
4. Finishing machine weight ≤ 14 kips, construction active wind speed = 20mph, and construction loading per ***SDG*** 2.13.
5. Bracing and connections are securely connected to each beam (moment resisting bracing frame).
6. 8.5 inch thick deck

C. For I shapes other than FIBs and AASHTO Type II beams, and prestressed I-beams erected using temporary shoring and/or spliced together using post-tensioning, design and detail project specific temporary bracing using the applicable philosophy above and include additional bracing types and/or details in the plans.

D. See ***SDG*** 11.6 for the Contractor’s bracing design requirements.

2. Add the following new section to ***Structures Design Guidelines*** Chapter 11:

11.6 Prestressed I-Beam Temporary Bracing Design

11.6.1 General

As required by Section 5 of the ***Specifications***, provide shop drawings and calculations for the temporary bracing design. Design temporary beam bracing in accordance with the FDOT ***Structures Manual***, the ***Specifications*** and the information contained in the Contract Documents.

11.6.2 Beam Stability

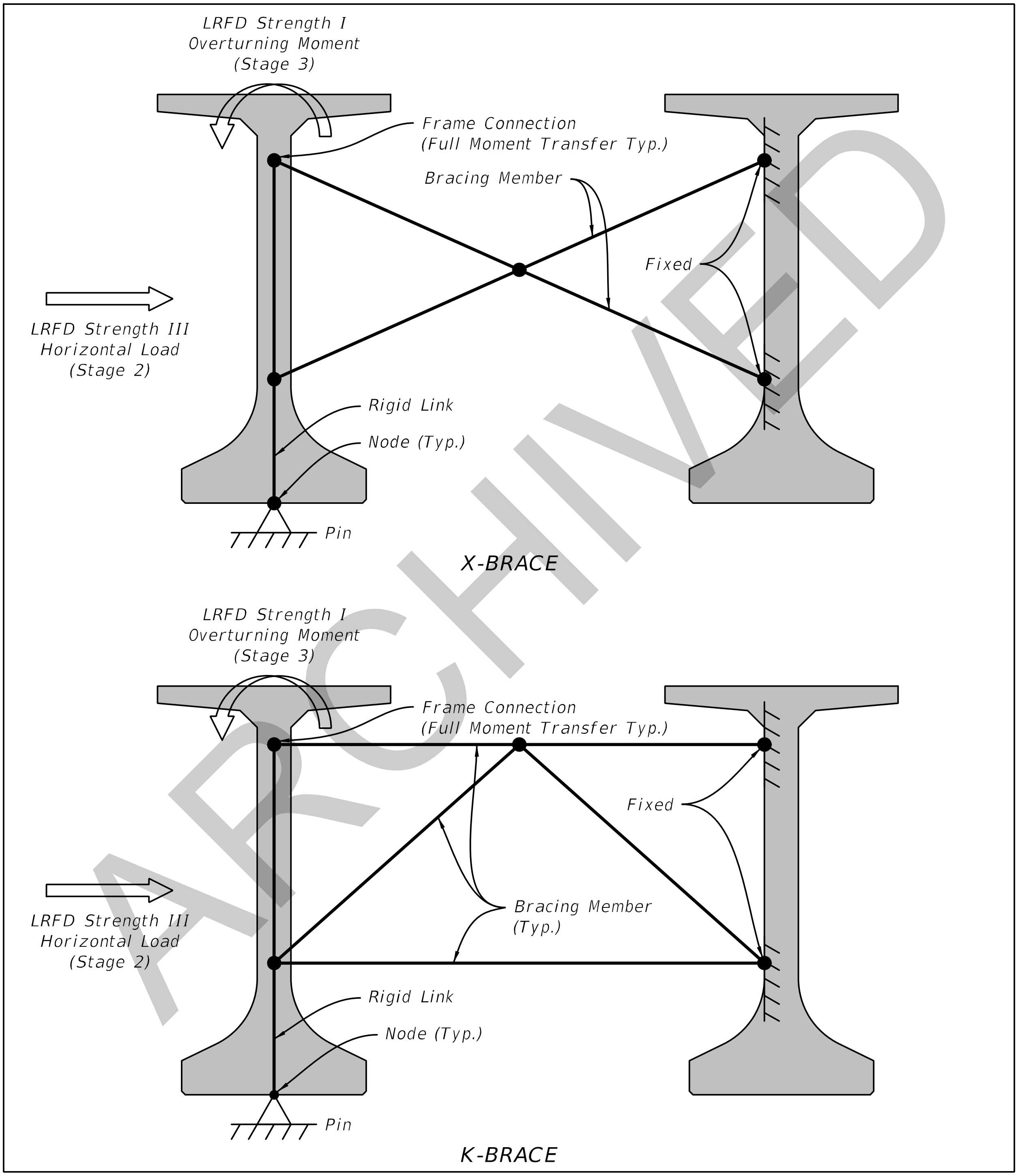
For stage definitions and I-beam stability requirements, see ***SDG*** 4.3.4.

11.6.3 Temporary Bracing Member Design

A. Anchor bracing, if required for the first beam placed, may be designed on a skew parallel with the centerline of bearing. Design all other bracing as moment resisting frames perpendicular to the beams (intermediate horizontal strut bracing alone provides no measurable gain in system capacity, see Reference 1). Place end bracing no greater than 4′-0″ from the centerline of bearings (applies to one end of bracing for skewed bridges). Use the same bracing in all bays. See the 'TABLE OF PRESTRESSED I-BEAM TEMPORARY BRACING MINIMUM REQUIREMENTS AND LOADS' in the Structures Plans for the minimum number of braces required to ensure beam stability.

B. Design bracing systems (members and connections) for the applied forces given in the 'TABLE OF PRESTRESSED I-BEAM TEMPORARY BRACING MINIMUM REQUIREMENTS AND LOADS'. For braced beams under wind loading (Stage 2), use the ***LRFD*** Strength III horizontal load to determine the brace forces. Assume the Stage 2 horizontal loads are applied perpendicular to the beam web at mid-height. For braced beams during deck casting (Stage 3), use the ***LRFD*** Strength I overturning moment to determine the brace forces. Assume the Stage 3 overturning moments are applied at the centerline of the beam at the top of the top flange. For simplicity, a 2D model with boundary conditions as shown in Figure 11.6-1 may be used to determine brace forces (see Reference 1). Apply Stage 2 and Stage 3 loads as separate load cases.

Figure 11.6-1 Recommended Structural Analysis Models for Determining X-brace and K-brace Forces



C. In addition to designing individual brace members based on the member forces, check the final brace system capacity C ≥ 1.0 of FIB beams using the following equations (not required for AASHTO Type II beams):

$$C = C_0 + \frac{\omega \cdot 620 \cdot \left(k_{brace}\right) \cdot e^{\frac{(-L)}{30}}}{k_{brace} + 1000000} - \frac{\sqrt{P_{avg}}}{1000000} \cdot \left[8 \cdot (L)^2 + 0.004 \cdot (L) \cdot k_{brace} - 5100 \cdot (L) - k_{brace} + 900000\right] - \frac{D \cdot P_U}{48 \cdot w_{beam}} \geq 1.0$$

$$C_0 = 39 \cdot e^{\frac{(-L)}{48}} + 0.5$$

Where:

C_0 = the capacity of an unanchored two beam FIB system in zero wind conditions (in terms of g).

C = the capacity of a two beam FIB system considering the effects from bracing, wind, and aerodynamic lift (in terms of g).

L = span length (ft)

ω = empirical scale factor to account for capacity increase from bracing at interior points. For end bracing only ω = 1, for end bracing and mid-span bracing ω = 1.4, for end bracing and quarter point bracing ω = 1.7.

k_{brace} = effective brace stiffness (kip-ft/rad). Determine k_{brace} by using the recommended structural model in Figure 11.6-2

D = FIB cross-section depth (in)

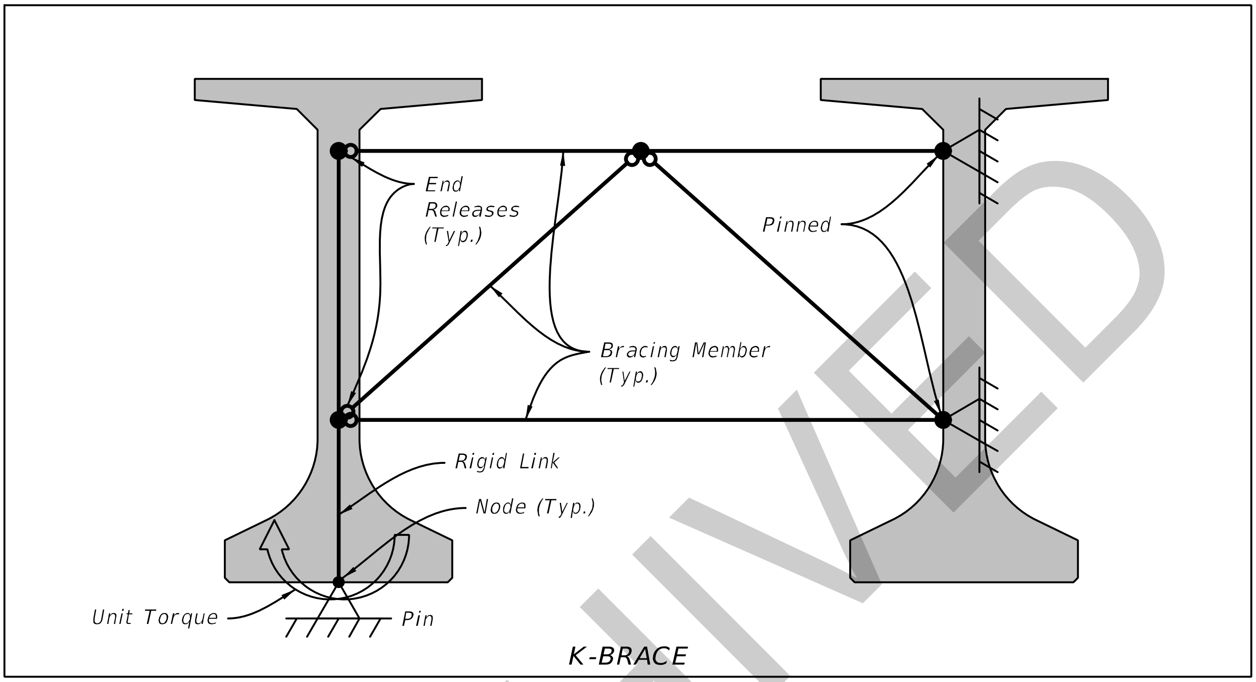
P_U = 1.5 times the unshielded wind load (psf)

P_{avg} = 1.5 times the average wind load pressure per beam for a 2 beam system considering skew (psf). For a zero skew bridge $P_{avg} = P_U /2$ since the second girder is shielded for its entire length.

w_{beam} = beam self-weight (lbf/ft)

For simplicity, a 2D model with a unit torque and boundary conditions as shown in Figure 11.6-2 may be used to determine brace system stiffness (see Reference 1).

Figure 11.6-2 Recommended Structural Analysis Model for Determining K-brace System Stiffness (X-brace similar)



D. Additional analysis methods for bracing design can be found in References 1 and 2. For braced beams during Stage 3, a data base method generated from 3D finite element models to calculate K-brace or X-brace forces directly is available (see Reference 2).

11.6.4 References

[1] Consolazio, G., Gurley, K., and Harper, Z. (2013). Bridge Girder Drag Coefficients and Wind-Related Bracing Recommendations, Structures Research Report No. 2013/87322, University of Florida, Gainesville, FL.

[2] Consolazio, G., and Edwards, T. (2014). Determination of Brace Forces Caused by Construction Loads and Wind Loads During Bridge Construction, Structures Research Report No. 2014/101350, University of Florida, Gainesville, FL.

3. Replace ***Structures Detailing Manual*** Section 5.2.F.3 with the following:

3. Construction Loads:

   Finishing Machine Load: ___ kips

   Finishing Machine Wheel Location beyond the edge of deck overhang: 6 inches

   Construction Live Load: 20 psf extended over the entire bridge width and 50-feet in longitudinal length centered on the finishing machine.

   Removable Deck Cantilever Timber Forms with Overhang Brackets: 15 psf

   Live load at or near the outside edge of deck during deck casting: 75 plf applied as a moving load over a length of 20-feet.

   Construction Inactive Basic Wind Speed Including Exposure Period Reduction

   Factor (RE): ___ MPH

   Velocity Pressure Exposure Coefficient (k_z): 1.14

   Construction Active Basic Wind Speed: 20 MPH

4. Add the following new paragraph to ***Structures Detailing Manual*** Section 15.2:

R. Include the following note on I-Beam framing plans: Temporary bracing locations are not shown. For locations of temporary bracing see the 'TABLE OF PRESTRESSED I-BEAM TEMPORARY BRACING MINIMUM REQUIREMENTS AND LOADS'.

5. Add the following new paragraph and figure to ***Structures Detailing Manual*** Section 15.5:

K. Complete the 'TABLE OF PRESTRESSED I-BEAM TEMPORARY BRACING MINIMUM REQUIREMENTS AND LOADS' as follows and include it in the plans.

Span No.: Indicate the span number.

Beam No.: Indicate the individual beam number or for simplicity use “All” when appropriate.

Stage 1:

Brace Ends Prior to Crane Release: Indicate yes or no.

Stage 2:

Total Lines of Bracing: Indicate the total number of lines of uniformly spaced bracing required per beam, including end bracing.

Minimum Number of Adjacent Beams Erected within 24 hours: Indicate the minimum number of beams that must be erected to be consistent with the bracing design assumptions, see ***SDG*** 4.3.4.B.

Horizontal Load at Each Brace: Indicate the ***LRFD*** Strength III horizontal load at each brace (kips).

Stage 3:

Total Lines of Bracing: Indicate the total number of lines of uniformly spaced bracing required per beam, including end bracing, not less than Stage 2 requirements.

Overturning Moment at Each Brace: Indicate the ***LRFD*** Strength I overturning moment at each brace (kip-ft).

Figure 15.5-3 Table of Prestressed I-Beam Temporary Bracing Minimum Requirements and Loads

PRESTRESSED BEAM STABILITY AND TEMPORARY BRACING NOTES:

1. *Ensure beam stability and design temporary beam bracing, including connections, in accordance with the Specifications and the FDOT Structures Manual.*
2. *Construction:*
   a. *Evaluate the beam stability and bracing requirements against the design assumptions including:*
      i. *Loadings given in the plans.*
      ii. *Beam Camber (less than 6 inches) and Beam Sweep (in compliance with Specification 450 requirements).*
      iii. *Bearings given in the plans.*
   b. *Securely connect bracing to each beam. Do not allow the bracing to exert any vertical force on the outer edge of the top flange. Preform all bolt holes in beams and fill after use in accordance with the Specifications.*

TABLE OF PRESTRESSED I-BEAM TEMPORARY BRACING MINIMUM REQUIREMENTS AND LOADS							Table Date 8-05-15
		STAGE 1	STAGE 2			STAGE 3	
SPAN NO.	BEAM NO.	BRACE ENDS PRIOR TO CRANE RELEASE?[1] (YES/NO)	TOTAL LINES OF BRACING[2,3,7]	MINIMUM NUMBER OF ADJACENT BEAMS ERECTED	HORIZONTAL LOAD AT EACH BRACE[4] (KIP)	TOTAL LINES OF BRACING[3,5,7]	OVERTURNING MOMENT AT EACH BRACE[6] (KIP-FT)

1. *Anchor Bracing loads to be determined by the Contractor.*
2. *Total lines of Stage 2 bracing, including end bracing, are required to be installed within 24 hours after initial beam placement.*
3. *Equally space bracing along the length of the beams allowing for variations due connection conflicts and skew.*
4. *LRFD Strength III loads applied to beam at brace point (see SDG 11.6).*
5. *Total lines of Stage 3 bracing, including end bracing, are required to be installed prior to deck placement.*
6. *LRFD Strength I overturning moment applied to beam at brace point (see SDG 11.6).*
7. *Submit shop drawings for temporary bracing plan including locations of preformed beam holes/inserts.*

6. Replace ***Structures Detailing Manual*** Section 23.7.A with the following:

A. Detail project specific temporary bracing based on the applicable portions of ***SDG*** 4.3.4 and include additional bracing types and/or details as required.

BACKGROUND

The majority of the changes are made to clarify prestressed concrete I-beam plan requirements for the Engineer of Record regarding beam stability and Contractor requirements regarding temporary bracing design. The pertinent information formerly contained in ***Design Standards*** Index 20005 and its associated ***Instructions for Design Standard*** have been moved to the ***SDG***, ***SDM*** and a CADD CEL.

The requirements of this bulletin are based on the following three references:

[1] Mast, R. (1993). "Lateral Stability of Long Prestressed Concrete Beams – Part 2", PCI Journal, Vol. 38, No. 1, January–February 1993, pp. 70–88.

[2] Consolazio, G., Gurley, K., and Harper, Z. (2013). Bridge Girder Drag Coefficients and Wind-Related Bracing Recommendations, Structures Research Report No. 2013/87322, University of Florida, Gainesville, FL.

[3] Consolazio, G., and Edwards, T. (2014). Determination of Brace Forces Caused by Construction Loads and Wind Loads During Bridge Construction, Structures Research Report No. 2014/101350, University of Florida, Gainesville, FL.

IMPLEMENTATION

These requirements are effective for all projects with January 2016 lettings and later.

Other items changed and already implemented in conjunction with this Bulletin are:

1. The removal of Index 20005 (Prestressed I-Beam Temporary Bracing) from the 2016 ***Design Standards***
2. Changes to the FDOT CADD CEL for Prestressed I-Beam Temporary Bracing (available at http://www.dot.state.fl.us/structures/CADD/standards/CurrentStandards/MicrostationDrawings.shtm)
3. FDOT Beam Stability Mathcad Program v2.2 (available at http://www.dot.state.fl.us/structures/ProgLib.shtm)

No changes related to this Bulletin are being made to the ***SDG*** wind load requirements or FDOT ***Specifications***.

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