# Florida Department of Transportation

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**STRUCTURES DESIGN BULLETIN C10-01**

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TO: District Directors of Production, District Design Engineers, District Structures Design Engineers, District Construction Engineers

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

COPIES: Brian Blanchard, Lora Hollingsworth

SUBJECT: New Temporary Bracing Requirements for Beams on New Bridge Projects

This Structures Design Bulletin (SDB) implements new requirements for bracing girders during construction for new bridge projects. The new Design Standard Index 20005, "Prestressed Beam Temporary Bracing," will be released with the January 2010 Interim Design Standards and a copy is included with Attachment 'B.'

**REQUIREMENTS**

1. 2010 Structures Manual, Volume 1: Structures Design Guidelines

    a. Section 2.4.3 Wind Loads During Construction – Replace item C with the following:

        C. Wind loads during construction shall be calculated per the equation for design wind pressure, Pz [Eq. 2-1], except the load factor ($\gamma_{WS}$) and basic wind speed for WS shall be found according to Table 2.4.3-1 and the pressure coefficient, *Cp*, shall be found according to Table 2.4.3-2.

**Table 2.4.3-1 Load Factors During Construction**

| LOAD COMBINATION LIMIT STATE | $\gamma_{WS}$ | BASIC WIND SPEED, V (MPH) | |
|---|---|---|---|
| | | Construction Inactive | Construction Active |
| STRENGTH III | 1.25 | Per Table 2.4.1-2 x $R_E$ | 20 MPH or expected wind speed, if higher |
| SERVICE I | 1.0 | Per Table 2.4.1-2 x $R_E$ | 20 MPH or expected wind speed, if higher |

Where:

Construction Inactive = periods during which construction activities associated with the superstructure do not take place. Ex: For a typical girder bridge, this includes non-work hours during which the girder bracing is to be present.

Construction Active = periods during which construction activities take place. Ex: For a typical girder bridge, this includes girder erection, form placement and deck concrete placement. It can be assumed that the construction active period for deck placement is in effect until the deck concrete hardens.

$R_E$ = 0.60 if the exposure period is less than one year. The exposure period is defined as the time period for which temporary load cases of the superstructure exist. For example, the exposure period for a girder bridge is defined as the time period from when the girder is set on the pedestals until the girder is made composite with the bridge deck, and the exposure period for a segmental bridge is defined as the time period from when segments are placed until spans are made continuous.

Note: Check limit states separately for Construction Inactive and Construction Active wind speeds.

**Table 2.4.3-2 Pressure Coefficient During Construction**

| COMPONENT TYPE | CONSTRUCTION CONDITION | PRESSURE COEFFICIENT ($C_p$) |
|---|---|---|
| I-Shaped Girder Superstructure | Deck forms not in place | 2.2 |
| | Deck forms in place | 1.1 |
| U-Shaped and Box Girder Superstructure | Deck forms not in place | 1.5 |
| | Deck forms in place | 1.1 |
| Flat Slab or Segmental Box Girder Superstructure | Any | 1.1 |
| Substructure | Any | 1.6 |

b. Section 4.3.1 General – Add the following to section 'C':
For transient loads during construction the tensile stress limit may be taken as $6\sqrt{f'_c}$.

c. Section 4.3.4 Temporary Bracing – Add this section as follows:

A. For concrete beam bridges, complete the 'Table of Temporary Bracing Variables,' 'Table of Wind Load Variables,' 'Table of Assumed Construction Loads,' and include the 'Beam Temporary Bracing' note (CADD Cell 20005). The tables and note are to assist the Contractor in design of the bracing members and connections.

B. Both roll stability and service stresses shall be evaluated for Service I limit states per Section 2.4 and AASHTO LRFD Bridge Design Specification Section 3.4.2 for the following construction conditions:

I. Girder Placement (Construction Active) – typical loads include the girder self-weight and construction active wind load; support conditions are un-braced beam set on bearing pads. If beams require bracing at these loads, specify in the 'Table of Temporary Bracing Variables' in the Structures Plans that the beam is to be braced at each end prior to crane release. It can be assumed that standard Florida-I beams less than 78 inches in height with spans less than 150 feet and skews between zero and 45 degrees are stable without bracing at girder placement.

II. Braced Girder (Construction Inactive) – typical loads include the girder self-weight and construction inactive wind load; support conditions are braced beam set on bearing pads.

III. Deck Placement (Construction Active) – typical loads include girder self-weight, construction active wind load and anticipated construction loads; support conditions are braced beam set on bearing pads.

C. Roll Stability is to be checked according to procedures demonstrated in:

- Mast, R.F (1989) "Lateral Stability of Long Prestressed Concrete Beams" Part I, *PCI Journal*, Vol 34, pp. 34-53. (Available at http://www.pci.org/view_file.cfm?file=JL-89-JANUARY-FEBRUARY-3.pdf)
- Mast, R.F (1993) "Lateral Stability of Long Prestressed Concrete Beams" Part II, *PCI Journal*, Vol 38, pp. 70-88. (Available at http://www.pci.org/view_file.cfm?file=JL-93-JANUARY-FEBRUARY-30.pdf and http://www.pci.org/view_file.cfm?file=JL-93-JANUARY-FEBRUARY-31.pdf)

The minimum factor of safety for cracking is 1.0, and the minimum factor of safety for failure is 1.5.

D. Working stresses during construction should be evaluated at the midspan of the girder. For simplicity, it may be assumed that full prestress losses have occurred.

E. Bracing design should be per Strength III limit states per Section 2.4 and AASHTO LRFD Bridge Design Specification Section 3.4.2.

*Commentary: The bridge designer shall check the stability of the beams after erection and calculate the bracing locations and forces based on construction wind loads and other assumed construction loads. The Contractor shall design the bracing members and connections based on forces given by the bridge designer.*

d. Section 6.8 Erection Scheme and Beam/Girder Stability – Replace Section 6.8 with the following:

For all steel girder, segmental beam or box girder bridges, and C.I.P. box girder bridges on falsework, include in the plans a workable erection scheme that addresses all major phases of erection. Show required temporary support locations and associated loads assumed in design. Coordinate temporary support locations with the Traffic Control Plans. For all bridges, investigate the stability of beams or girders subjected to wind loads during construction. See Section 4.3.4 for plan requirements for pre-tensioned beams. For the evaluation of stability during construction use wind loads, limit states and temporary construction loads included in the *Structures Design Guidelines* Section 2.4 and the *AASHTO LRFD Bridge Design Specifications*. For information not included in the *SDG* or *LRFD*, refer to the *AASHTO Guide Design Specifications for Bridge Temporary Works* and the *AASHTO Construction Handbook for Bridge Temporary Works.*

*Commentary: Investigate superstructure stability at all major phases of construction consistent with the erection scheme shown in the plans. The Contractor is responsible for evaluating the stability of individual components during erection.*

2. Standard Specifications
   a. Section 5-1.4.5.6 Beam and Girder Temporary Bracing – Tentative changes are as follows, to be implemented with the January 2011 Standard Specifications:

      The Contractor is solely responsible for ensuring stability of beams and girders during all handling, storage, shipping and erection. Adequately brace beams and girders to resist wind, weight of forms and other temporary loads, especially those eccentric to the vertical axis of the products, considering actual beam geometry and support conditions during all stages of erection and deck construction. At a minimum, brace girders at each end of each span. Develop the required designs following the AASHTO LRFD Bridge Design Specifications (LRFD), substituting wind loads found in the Structures Design Guidelines (SDG) Section 2.4.3. For information not included in the SDG or LRFD, refer to the AASHTO Guide Design Specifications for Bridge Temporary Works and the AASHTO Construction Handbook for Bridge Temporary Works.

      For Construction Affecting Public Safety and when temporary bracing requirements are shown in the plans, submit a Specialty Engineer's signed and sealed design calculations for bracing members and connections, and for prestressed concrete beams, submit a certification statement that construction loads do not exceed the assumed loads shown in the plans.

      For Construction Affecting Public Safety and when temporary bracing requirements are not shown in the plans or when the Contractor proposes to use a bracing system that differs from that specified in the plans and technical special provisions, submit a Specialty Engineer's signed and sealed plans and calculations for stability for all beams and girders and the plans and design calculations for bracing members and connections.

      Transmit the submittal and copies of the transmittal letters in accordance with the requirements of 5-1.4.5.1 through 5-1.4.5.3, as appropriate.

3. Design Standards
   a. Standards relating to the bracing of beams for wind load will be released with the January 2010 Interims, and are included in Attachment 'B' of this bulletin.

**COMMENTARY**

The following attachments are included for evaluation of the effect of these changes:

Attachment 'A' – Example Calculations

Attachment 'B' – Design Standard Index 20005, Instructions for Structures Related Design Standard Index 20005 (SDM Vol. III), CADD Cell 20005 (Table of Temporary Bracing Variables,' 'Table of Wind Load Variables,' 'Table of Assumed Construction Loads,' and 'Beam Temporary Bracing' note)

In order to standardize the methods of temporary bracing, Design Standards relating to bracing and a MathCAD Beam Stability Program have been developed. The Design Standard relating to bracing, Index No. 20005, shows a sample beam and bracing layout, several bracing configurations, and includes standard notes. The bracing sections are schematic and bracing member sizes and connections are not specified, as the design of bracing members and connections is left to the Contractor and the Specialty Engineer. However, the bracing sections do indicate the geometry in which bracing should be placed, and whether tension or compression members are required, in an effort to assist Contractors in developing a design which is in line with FDOT desired bracing schemes. The Design Standard is intended to be used with the 'Table of Temporary Bracing Variables,' 'Table of Wind Load Variables,' 'Table of Assumed Construction Loads,' and the 'Beam Temporary Bracing' note, all included in CADD Cell 20005.

The 'Table of Temporary Bracing Variables' includes the span number, maximum un-braced length of the beams, forces at each bracing point, number of bracing lines required, and whether or not end bracing is required prior to crane release. The 'Table of Wind Load Variables' includes the wind speed, velocity pressure exposure coefficient, and gust effect factor. The 'Table of Assumed Construction Loads' includes all construction loading assumptions made by the bridge designer. The tables are to be completed by the bridge designer and included in the plans to assist the Contractor in designing bracing members and connections. The 'Beam Temporary Bracing' note, which clarifies the Contractor's responsibilities relating to bracing, is also to be included in the plans by the bridge designer.

The inclusion of temporary bracing requirements in the design phase is a change in policy. The Contractor is responsible for all aspects of handling, shipping, and erection but the designer is responsible for specifying bracing requirements for stability of the beam once seated on the substructure. In addition, the designer is to investigate beam stability at erection, while seated on the substructure without bracing and subjected to 20 mph wind (construction active wind) and indicate whether or not end bracing is required prior to crane release. Design Standard Index No. 20005, Instructional Design Standard Index 20005, and CADD Cell 20005 are included in Attachment 'B' of this bulletin.

## BACKGROUND

Recent national events had heightened awareness of the importance of the temporary bracing of the bridge beams and girders during construction. This combined with the need to give the contractor the bracing information for bidding purposes prompted this policy change. Historically, bridge designers designed the beams or girders for the final conditions and the contactor was responsible for the stability of the beam during the construction period. This division of responsibility does not account for the fact that the girder stability is part of the girder design or at least influenced by the girder design. This will eliminate the need for multiple contractors to calculate the bracing forces during bidding.

This Structures Design Bulletin implements a policy change for calculating and showing the bracing requirement in the plans. The contractor is responsible for verifying that the construction loads do not exceed the assumed loads in the design. The contractor is also responsible for the design of the bracing members and connections for the bracing forces. This policy will place the responsibility for the bracing forces with the designer who selects the bridge type, span length, girder size, and all other variables that affect the beam stability.

## IMPLEMENTATION

All requirements for bracing contained herein are effective immediately for all design projects with a letting date on or after July 2011. This bulletin is not mandatory for projects currently under construction or let prior to July 2011, but Districts may elect to incorporate the requirements into ongoing construction and design projects at their discretion.

## CONTACT

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# Concrete I-Girder
# Beam Stability Program

**Project =**
**DesignedBy =**
**CheckedBy =**
**BackCheckedBy =**

*These are calculations for the Lateral Stability of Precast Concrete Bridge Girders during construction. Instructions for use of this program are as follows:*

*1. Input the items under the girder properties, geometry, and loads sections highlighted in tan. For the girders listed in the "Girder Type" pull-down menu, un-highlighted girder properties are automatically defined. For any other girder types, properties must be manually defined. The number of intermediate bracing points, from zero to six, represents any intermediate bracing that is to be present between the points of bearing. A value of zero represents no intermediate bracing points between the bearing points.*

*2. Check that the stress and stability checks (highlighted in yellow) read "OK." The check for stability at girder placement may read "Not OK," but for this case, girders must be braced prior to crane release.*

*3. If requirement 2 is not met, revise the number of intermediate brace points.*

*4. The bracing forces and maximum un-braced length are given at the end of calculations.*

## Girder Variables:

| | |
|---|---|
| *Girder Type* | Girder := 78-in Florida-I Beam |
| *Unit weight of Concrete* | $w_c := 150 \cdot pcf$ |
| *Unit weight of Concrete for deck pour* | $w_{cd} := 160 \cdot pcf$ *(160 pcf per AASHTO Guide Design Specifications for Temporary Works)* |
| *Concrete Strength* | $f_{c'} := 8.5 \cdot ksi$ |
| *Effective Prestressing Force (may assume all losses have occurred)* | $P_e := 2189 \cdot kip$ |
| *Eccentricity of Prestressing* | $e := 29 \cdot in$ |

## Geometry:

*Beam Span Length (centerline to centerline bearing)* $L := 182 \cdot ft$

*Number of Intermediate Bracing Points, (from 0 to 6)* $n_b := 2$

*Sweep Tolerance* $tol_S := \frac{\frac{1}{8} \cdot in}{10 \cdot ft}$

*Initial imperfection of bracing* $e_b := .25 \cdot in$

*Skew Angle (between 0 and 60)* $\phi := 45 \cdot deg$

*Beam Spacing* $S := 6 \cdot ft$

*Number of Beams in X-Section (from 2 to 12)* $n_{beam} := 7$

*Overhang Length (measured from centerline of exterior beam)* $OH := 3 \cdot ft$

*Deflection of Deck Limit at Edge of Cantilever (recommend .25 in)* $\delta_{max} := .25 \cdot in$

*Deck thickness (total, including IWS)* $t_d := 8.5 \cdot in$

## Bearing Pad Properties:

*Bearing pad plan dimensions (a=width, b=length)* $a := 32 \cdot in$ $b := 10 \cdot in$

*Thickness of internal elastomer layer* $t := .5 \cdot in$

*Number of interior layers of elastomer* $n := 5$

*Elastomer Shear Modulus* $G_{bp} := 127.5 \cdot psi$

*When the thickness of the exterior layer of elastomer is equal to or greater than one-half the thickness of an interior layer, the parameter, n, may be increased by one-half for each such exterior layer.*

*Tilt Angle of Support (Bearing Pad Construction Tolerance, recommend .01)* — $\alpha := .01$

*Distance from Bottom of Beam to Roll Axis (half bearing pad thickness)* — $h_r := 1.25 \cdot in$

## Loads:

*Basic Wind Speed* — $V_B := 150 \cdot mph$

*Wind Speed Factor for Construction Inactive Wind Speed* — $R_E := 0.6$ $\qquad V := R_E \cdot V_B = 90 \cdot mph$

*Construction Active Wind Speed (20 MPH recommended)* — $V_E := 20 \cdot mph$

*Construction Wind Load Factor* — $\gamma := 1.25$

*Gust effect factor* — $G := 0.85$

*Pressure Coefficient, single girder* — $C_{pg} := 2.2$

*Pressure Coefficient, entire bridge section* — $C_p := 1.1$

*Bridge Height, measured to mid-height of beam (ft)* — $Height := 60 \cdot ft$

*Velocity Pressure Exposure Coefficient*

$$K_z := \max\left[2.01 \cdot \left(\frac{Height}{900 \cdot ft}\right)^{.2105}, 0.85\right] = 1.137$$

*Construction Active Wind Load for single girder*

$$w_{wE} := 0.00256 \cdot K_z \cdot G \cdot C_{pg} \cdot \left(\frac{V_E}{mph}\right)^2 \cdot psf = 2.177 \cdot psf$$

*Construction Inactive Wind Load for single girder*

$$w_w := 0.00256 \cdot K_z \cdot G \cdot C_{pg} \cdot \left(\frac{V}{mph}\right)^2 \cdot psf = 44.075 \cdot psf$$

*Construction Active Wind Load for entire bridge section*

$$w_{wD} := 0.00256 \cdot K_z \cdot G \cdot C_p \cdot \left(\frac{V_E}{mph}\right)^2 \cdot psf = 1.088 \cdot psf$$

*Weight of build-up* — $w_b := 50 \cdot plf$

*Weight of forms (20 psf recommended)*

$w_f := 20 \cdot psf$

*Live loads during deck pour (20 psf and 75 plf at edge of overhang per AASHTO Guide Design Specifications for Temporary Works)*

$w_l := 20 \cdot psf$

$P_l := 75 \cdot plf$

*Total Weight of finishing machine*

$w_{fm} := 20 \cdot kip$

*(recommend 10 kips for bridge widths less than 45 feet and 20 kips otherwise)*

*Wheel Location of finishing machine in relation to edge of overhang, positive is to exterior of overhang edge, negative is to interior of overhang edge*

$d_{fm} := 2.5 \cdot in$

*(+2.5 in. recommended)*

## Girder Properties

*Reference to Excel Properties file*

Properties := READFILE("BeamProp.xls" , "Excel" )

*Unbraced Length of Beam*

$$L_b := \frac{L}{n_b + 1} = 60.667\,ft$$

*Height*

$$h := Properties_{Girder,1} \cdot in = 78 \cdot in$$

*Top flange width*

$$b_t := Properties_{Girder,2} \cdot in = 48 \cdot in$$

*Bottom flange width*

$$b_b := Properties_{Girder,3} \cdot in = 38 \cdot in$$

*Modulus of Elasticity*

$$E_c := 0.9 \cdot 57000 \cdot \left(\frac{f_{c'}}{psi}\right)^{0.5} \cdot psi = 4.73 \times 10^3 \cdot ksi$$

*Shear Modulus*

$$G_{shear} := .416667 \cdot E_c = 1.971 \times 10^3 \cdot ksi$$

*Area of Concrete*

$$A_c := Properties_{Girder,4} \cdot in^2 = 1.101 \times 10^3 \cdot in^2$$

*Moment of Inertia, about x-axis*

$$I_x := Properties_{Girder,5} \cdot in^4 = 904567 \cdot in^4$$

*Moment of Inertia, about y-axis* $I_y := Properties_{Girder,6} \cdot in^4 = 82367 \cdot in^4$

*Distance from CG to top of beam* $y_t := Properties_{Girder,7} \cdot in = 43.4 \cdot in$

*Distance from CG to bottom of beam* $y_b := Properties_{Girder,8} \cdot in = 34.6 \cdot in$

*Torsional Constant* $J := Properties_{Girder,9} \cdot in^4 = 33291 \cdot in^4$

*Section Moduli*

$S_t := \frac{I_x}{y_t} = 20843 \cdot in^3$ $\quad S_b := \frac{I_x}{y_b} = 26144 \cdot in^3$ *Section moduli about x-axis*

$S_{yt} := \frac{2 \cdot I_y}{b_t} = 3432 \cdot in^3$ $\quad S_{yb} := \frac{2 \cdot I_y}{b_b} = 4335 \cdot in^3$ *Section moduli about y-axis*

*Self-weight of beam and deck* $w := A_c \cdot w_c = 1.146 \times 10^3 \cdot plf$ $\quad w_d := t_d \cdot w_{cd} = 113.333 \cdot psf$

## Lateral Deflection and Eccentricity of Girder Center of Gravity:

*Maximum Lateral Deflection of Uncracked Section*

$$z_o := \frac{w \cdot L^4}{120 \cdot E_c \cdot I_y} = 46.496 \cdot in$$

*This is the theoretical maximum lateral deflection of the beam based on beam self-weight if cracking did not occur*

*Eccentricity due to Sweep*

$$e_s := \min\left(1.5 \cdot in, L \cdot tol_S\right) \frac{2}{3} = 1 \cdot in$$

*Based on the sweep tolerance and 1.5" limit per the Specifications, this is maximum sweep that could occur, the 2/3 factor is included because the average location of the CG over the length of the beam is 2/3 of the maximum sweep*

*Eccentricity due to construction inactive wind speed*

$$e_w := \frac{w_w \cdot h \cdot L^4}{120 \cdot E_c \cdot I_y} = 11.619 \cdot in$$

*Eccentricity due to wind loading at construction active wind speed, girder only*

$$e_{wE} := \frac{w_{wE} \cdot h \cdot L^4}{120 \cdot E_c \cdot I_y} = 0.574 \cdot in$$

*Lateral deflection due to wind, based on uncracked section*

*Eccentricity due to wind loading at construction active wind speed, entire bridge section*

$$e_{wD} := \frac{w_{wD} \cdot h \cdot L^4}{120 \cdot E_c \cdot I_y} = 0.287 \cdot in$$

## Bearing Pad Rotational Stiffness

$b\_a := (.5\ \ .6\ \ .7\ \ .75\ \ .8\ \ .9\ \ 1\ \ 1.2\ \ 1.4\ \ 2\ \ 4\ \ 10\ \ 1000)$

*Range of possible length:width ratios of bearing pad*

$C := (136.7\ \ 116.7\ \ 104.4\ \ 100\ \ 96.2\ \ 90.4\ \ 86.2\ \ 80.4\ \ 76.7\ \ 70.8\ \ 64.9\ \ 61.9\ \ 60)$

*Range of possible coefficient based on length:width ratio*

$C' := \text{linterp}\left(b\_a^T, C^T, \frac{b}{a}\right) = 174.2$

*Coefficient based on length:width ratio*

*Effect of Skew on Stiffness (coefficient)*

$Ang := (0\ \ 15\ \ 30\ \ 45\ \ 60)$

$Stiffness := (.8883\ \ .5922\ \ .4666\ \ .3948\ \ .323)$

*Range of stiffness coefficients per skew per UF Structures Research Report 2007/52290*

*Bearing Pad Rotational Stiffness*

$$K_\theta := \text{linterp}\left(Ang^T, Stiffness^T, \frac{\phi}{deg}\right)\cdot\frac{G_{bp}\cdot a^5\cdot b}{C'\cdot n\cdot t^3} = 155134.736\cdot\frac{kip\cdot in}{rad}$$

*Coefficient for Reaction at Bracing based on number of brace points, i=intermediate, e=end*

$$k_{vi} := \begin{pmatrix} 0 \\ 1.25 \\ 1.1 \\ 1.143 \\ 1.132 \\ 1.135 \\ 1.134 \end{pmatrix} \qquad k_{ve} := \begin{pmatrix} .5 \\ .375 \\ .4 \\ .393 \\ .395 \\ .395 \\ .395 \end{pmatrix}$$

$K_{vi} := k_{vi_{n_b}} = 1.1$

$K_{ve} := k_{ve_{n_b}} = 0.4$

$$k_m := \begin{pmatrix} .12513 & .12513 & .12513 & .12513 & .12513 & .12513 & .12513 & .12513 & .12513 & .12513 & .12513 \\ .07818 & .05212 & .03905 & .03128 & .02874 & .02697 & .02569 & .02472 & .02395 & .02333 & .02281 \\ .06396 & .04357 & .03337 & .02725 & .02317 & .02026 & .01808 & .01637 & .01501 & .01391 & .01344 \\ .06481 & .04321 & .0324 & .02592 & .02181 & .01899 & .01689 & .01526 & .01395 & .01289 & .01199 \\ .06349 & .04294 & .03267 & .02651 & .02239 & .01946 & .01726 & .01554 & .01417 & .01306 & .01212 \\ .06377 & .04251 & .03189 & .02551 & .02136 & .01847 & .0163 & .01462 & .01327 & .01216 & .01125 \\ .06298 & .04227 & .0319 & .02569 & .02155 & .01858 & .01636 & .01464 & .01326 & .01213 & .01119 \end{pmatrix}$$

*Coefficient for Bending Moment in Girder based on number of brace points*

$K_M := k_{m_{n_b, n_{beam}-2}} = 0.02026$

## Calculation of Bending Moments:

*Unfactored vertical load during deck placement for ext. beam (not including finishing machine)*

*Includes self-wt of girder, build-up, forms, wet concrete deck, and construction live loads*

$$w_{D.ext} := w + w_b + P_l + \left(w_d + w_l\right)\cdot(.5\cdot S + OH) + w_f\cdot\left(.5\cdot S + OH - b_t\right) = 2.11\cdot klf$$

$$w_{D.int} := w + w_b + \left(w_d + w_l\right)\cdot S + w_f\cdot\left(S - b_t\right) = 2.036\cdot klf$$

*Strength I Torsional Distributed Overhang Moment during deck placement*

$$M_c := \left[1.25\cdot\left(w_d + w_f\right) + 1.5\cdot w_l\right]\cdot\left(OH - .5\cdot b_t\right)\cdot\left[.5\cdot b_t + .5\cdot\left(OH - .5\cdot b_t\right)\right] + 1.5\cdot P_l\cdot OH = 0.83\cdot\frac{kip\cdot ft}{ft}$$

*Includes all construction loads except finishing machine*

*Strength I Torsional Finishing Machine Moment* $M_{fm} := 1.25\cdot .5\cdot w_{fm}\cdot\left(OH + d_{fm}\right) = 40.104\cdot kip\cdot ft$

*Finishing Machine Moment at each exterior girder*

*Lateral Moment Due to Construction Inactive wind speed* $M_w := K_M\cdot w_w\cdot h\cdot L^2 = 2307\cdot kip\cdot in$

*Vertical Moment due to girder self-weight* $M_g := \frac{w\cdot L^2}{8} = 56962\cdot kip\cdot in$

*Lateral Moment Due to Construction Active Wind speed, braced condition* $M_{wE} := K_M\cdot w_{wE}\cdot h\cdot L^2 = 114\cdot kip\cdot in$

*Lateral Moment Due to Construction Active Wind speed, unbraced condition* $M_{wE.u} := .125\cdot w_{wE}\cdot h\cdot L^2 = 703\cdot kip\cdot in$

*Vertical Moment due to self-weight and construction loads during deck placement, exterior girder*

$$M_{gD} := \frac{w_{D.ext}\cdot L^2 + w_{fm}\cdot L}{8} = 110369\cdot kip\cdot in$$

## Service Stress Check for Girder Placement, prior to beam bracing:

*Camber (approx.)*

$$\delta_c := \frac{L^2\cdot\left(P_e\cdot e - \frac{5w\cdot L^2}{48}\right)\cdot 2}{8\cdot E_c\cdot I_x} = 4.463\cdot in$$

*Assumes creep factor is 2.0*

*Distance from Center of Gravity to Roll Axis*

$$y := y_b + h_r + \delta_c\cdot\frac{2}{3} = 38.825\cdot in$$

*The camber is multipled by 2/3 because the average location of the CG over the length of the beam is 2/3 of the maximum camber*

*Elastic Rotational Spring Constant (sum of 2 bearing pads)*

$$K_\theta = 155134.736 \cdot \frac{kip \cdot in}{rad}$$

*Radius of Stability*

$$r := \frac{K_\theta}{w \cdot L} = 61.959\,ft$$

*Per Mast Part 2, r is the height at which the total beam weight could be placed to cause neutral equilibrium with the spring for a given small angle*

*Sign convention is tension=positive, compression=negative*

*Stress at Top of Beam, Tension*

$$f_{ttE} := -\frac{P_e}{A_c} + \frac{P_e \cdot e}{S_t} - \frac{M_g}{S_t} + \frac{M_{wE.u}}{S_{yt}} = -1.471 \cdot ksi$$

*Stress at Top of Beam, Compression*

$$f_{tcE} := -\frac{P_e}{A_c} + \frac{P_e \cdot e}{S_t} - \frac{M_g}{S_t} - \frac{M_{wE.u}}{S_{yt}} = -1.881 \cdot ksi$$

*Compression Check*

$$Ck_{E.t.comp} := \text{if}\left(f_{tcE} \le 6 \cdot \sqrt{\frac{f_{c'}}{psi}} \cdot psi \wedge f_{tcE} \ge -0.6 \cdot f_{c'}, 1, 0\right) = 1$$

*Tension Check*

$$Ck_{E.t.tens} := \text{if}\left(f_{ttE} \le 6 \cdot \sqrt{\frac{f_{c'}}{psi}} \cdot psi \wedge f_{ttE} \ge -0.6 \cdot f_{c'}, 1, 0\right) = 1$$

*Stress at Bottom of Beam, Tension*

$$f_{btE} := -\frac{P_e}{A_c} - \frac{P_e \cdot e}{S_b} + \frac{M_g}{S_b} + \frac{M_{wE.u}}{S_{yb}} = -2.076 \cdot ksi$$

*Stress at Bottom of Beam, Compression*

$$f_{bcE} := -\frac{P_e}{A_c} - \frac{P_e \cdot e}{S_b} + \frac{M_g}{S_b} - \frac{M_{wE.u}}{S_{yb}} = -2.4 \cdot ksi$$

*Compression Check*

$$Ck_{E.b.comp} := \text{if}\left(f_{bcE} \le 6 \cdot \sqrt{\frac{f_{c'}}{psi}} \cdot psi \wedge f_{bcE} \ge -0.6 \cdot f_{c'}, 1, 0\right) = 1$$

*Tension Check*

$$Ck_{E.b.tens} := \text{if}\left(f_{btE} \le 6 \cdot \sqrt{\frac{f_{c'}}{psi}} \cdot psi \wedge f_{btE} \ge -0.6 \cdot f_{c'}, 1, 0\right) = 1$$

*Check for stress at girder placement*

$$Ck_{stress.plcmnt} := \text{if}\left(\min\left(Ck_{E.t.comp}, Ck_{E.t.tens}, Ck_{E.b.comp}, Ck_{E.b.tens}\right) = 1, \text{"OK"}, \text{"Not OK"}\right) = \text{"OK"}$$

## Roll Stability Check for Girder Placement, prior to beam bracing:

*Modulus of Rupture*

$$f_r := 7.5\cdot\sqrt{f_c'}\cdot\sqrt{psi} = 691.466\cdot psi$$

*Lateral Cracking Moment*

$$M_{lat} := \min\left[\frac{(f_r - f_{ttE})\cdot I_y}{\left(\frac{b_t}{2}\right)}, \frac{(f_r - f_{btE})\cdot I_y}{\left(\frac{b_b}{2}\right)}\right] = 7422.697\cdot kip\cdot in$$

*Y-direction moment that causes cracking*

*Rotation Angle at Cracking*

$$\theta_{cr} := \frac{M_{lat}}{M_g} = 0.13\cdot rad$$

*Rotation Angle at Failure*

$$\theta_f := \min\left[0.4, \frac{5\cdot z_o\cdot\alpha + \left[(5\cdot z_o\cdot\alpha)^2 + 10\cdot z_o\cdot\left(e_s + e_{wE} + \alpha\cdot z_o + 2.5\cdot e_{wE}\cdot\alpha + y\cdot\alpha + \frac{w_{wE}\cdot h^2}{2\cdot w}\right)\right]^{.5}}{5\cdot z_o}\right] = 0.169$$

*θ and $\theta_f$ are adapted from Mast Part 2 to include effects of erection wind load*

*Final Rotation*

$$\theta := \frac{\alpha\cdot r + e_s + e_{wE} + \frac{w_{wE}\cdot h^2}{2\cdot w}}{r - y - z_o} = 0.0144\cdot rad$$

*Factor of Safety for Cracking (Unbraced Beam)*

$$FS_{cr} := \frac{r\cdot(\theta_{cr} - \alpha)}{z_o\cdot\theta_{cr} + e_s + e_{wE} + y\cdot\theta_{cr} + \frac{w_{wE}\cdot h^2}{2\cdot w}} = 6.8$$

*Factors of safety are adapted from Mast Part 2 to include effects of erection wind load*

*Factor of Safety for Failure (Unbraced Beam)*

$$FS_f := \frac{r\cdot(\theta_f - \alpha)}{z_o\cdot(1 + 2.5\cdot\theta_f)\cdot\theta_f + e_s + e_{wE}\cdot(1 + 2.5\cdot\theta_f) + y\cdot\theta_f + \frac{w_{wE}\cdot h^2}{2\cdot w}} = 5.9$$

*Check for stability at girder placement*

$$Ck_{stab.plcmnt} := \text{if}\left[(\theta \ge 0) \wedge (FS_{cr} \ge 1) \wedge (FS_f \ge 1.5), \text{"OK"}, \text{"Not OK"}\right] = \text{"OK"}$$

## Service Stress Check for braced beam, prior to deck placement:

*Stress at Top of Beam, Tension*

$$f_{tt} := -\frac{P_e}{A_c} + \frac{P_e \cdot e}{S_t} - \frac{M_g}{S_t} + \frac{M_w}{S_{yt}} = -1.004 \cdot ksi$$

*Sign convention is tension=positive, compression=negative*

*Stress at Top of Beam, Compression*

$$f_{tc} := -\frac{P_e}{A_c} + \frac{P_e \cdot e}{S_t} - \frac{M_g}{S_t} - \frac{M_w}{S_{yt}} = -2.348 \cdot ksi$$

*Compression Check*

$$Ck_{B.t.comp} := \text{if}\left(f_{tc} \le 6 \cdot \sqrt{\frac{f_{c'}}{psi}} \cdot psi \wedge f_{tc} \ge -0.6 \cdot f_{c'}, 1, 0\right) = 1$$

*Tension Check*

$$Ck_{B.t.tens} := \text{if}\left(f_{tt} \le 6 \cdot \sqrt{\frac{f_{c'}}{psi}} \cdot psi \wedge f_{tt} \ge -0.6 \cdot f_{c'}, 1, 0\right) = 1$$

*Stress at Bottom of Beam, Tension*

$$f_{bt} := -\frac{P_e}{A_c} - \frac{P_e \cdot e}{S_b} + \frac{M_g}{S_b} + \frac{M_w}{S_{yb}} = -1.706 \cdot ksi$$

*Stress at Bottom of Beam, Compression*

$$f_{bc} := -\frac{P_e}{A_c} - \frac{P_e \cdot e}{S_b} + \frac{M_g}{S_b} - \frac{M_w}{S_{yb}} = -2.771 \cdot ksi$$

*Compression Check*

$$Ck_{B.b.comp} := \text{if}\left(f_{bc} \le 6 \cdot \sqrt{\frac{f_{c'}}{psi}} \cdot psi \wedge f_{bc} \ge -0.6 \cdot f_{c'}, 1, 0\right) = 1$$

*Tension Check*

$$Ck_{B.b.tens} := \text{if}\left(f_{bt} \le 6 \cdot \sqrt{\frac{f_{c'}}{psi}} \cdot psi \wedge f_{bt} \ge -0.6 \cdot f_{c'}, 1, 0\right) = 1$$

*Check for stress at braced condition*

$$Ck_{stress.braced} := \text{if}\left(\min\left(Ck_{B.t.comp}, Ck_{B.t.tens}, Ck_{B.b.comp}, Ck_{B.b.tens}\right) = 1, \text{"OK"}, \text{"Not OK"}\right) = \text{"OK"}$$

## Roll Stability Check for braced beam, prior to deck placement:

*Initial Rotation* $$\theta_i := \frac{\alpha \cdot r + e_s}{r - y - z_o} + \frac{\min(e_b, e_w)}{y} = 0.019$$

*Maximum Torque between bracing points* $$T_B := w \cdot L \cdot e_w = 202.031 \cdot kip \cdot ft$$

*Twist due to torque* $$\phi_B := \frac{T_B \cdot .5 \cdot L_b}{G_{shear} \cdot J} = 0.013$$

*Total Rotation* $$\theta_w := \theta_i + \phi_B = 0.0327$$

*Rotation Limits* $$\theta_{w.max} := \min(\theta_{cr}, 5 \cdot deg) = 0.087$$

*Wind Load Rotation Check* $$FS_{\theta w} := \frac{\theta_{w.max}}{\theta_w} = 2.668$$

$$Ck_{stab.braced} := if(FS_{\theta w} \geq 1, \text{"OK"}, \text{"Not OK"}) = \text{"OK"}$$

*The initial rotation is caused by the imperfections in the girder and girder support. Additionally, it can be expected that the wind load will cause the maximum "play" in the bracing to be achieved, which results in an eccentricity of $e_b$. The initial rotation is the maximum rotation that is seen at the bracing points. Any additional rotation is between the bracing points in the form of torque. The torque is caused by the fact that the CG of the beam is not in line with the supports due to eccentricity.*

*It makes sense to prevent cracking of the beam, as the strength of the beam is compromised once cracking occurs. A reasonable upper bound limit is 5 degrees. Per Mast Part 2, cracking occurs in many beams at 5 degrees.*

## Service Stress Check for braced beam, during deck placement:

*Sign convention is tension=positive, compression=negative*

*Stress at Top of Beam, Tension* $$f_{ttD} := -\frac{P_e}{A_c} + \frac{P_e \cdot e}{S_t} - \frac{M_{gD}}{S_t} + \frac{M_{wE}}{S_{yt}} = -4.205 \cdot ksi$$

*Stress at Top of Beam, Compression* $$f_{tcD} := -\frac{P_e}{A_c} + \frac{P_e \cdot e}{S_t} - \frac{M_{gD}}{S_t} - \frac{M_{wE}}{S_{yt}} = -4.272 \cdot ksi$$

*Compression Check* $$Ck_{D.t.comp} := if\left(f_{tcD} \leq 6 \cdot \sqrt{\frac{f_{c'}}{psi}} \cdot psi \wedge f_{tcD} \geq -0.6 \cdot f_{c'}, 1, 0\right) = 1$$

*Tension Check* $$Ck_{D.t.tens} := if\left(f_{ttD} \leq 6 \cdot \sqrt{\frac{f_{c'}}{psi}} \cdot psi \wedge f_{ttD} \geq -0.6 \cdot f_{c'}, 1, 0\right) = 1$$

*Stress at Bottom of Beam, Tension* $$f_{btD} := -\frac{P_e}{A_c} - \frac{P_e \cdot e}{S_b} + \frac{M_g}{S_b} + \frac{M_{wE}}{S_{yb}} = -2.212 \cdot ksi$$

*Stress at Bottom of Beam, Compression*

$$f_{bcD} := -\frac{P_e}{A_c} - \frac{P_e \cdot e}{S_b} + \frac{M_g}{S_b} - \frac{M_{wE}}{S_{yb}} = -2.265 \cdot ksi$$

*Compression Check*

$$Ck_{D.b.comp} := \text{if}\left(f_{bcD} \le 6 \cdot \sqrt{\frac{f_{c'}}{psi}} \cdot psi \wedge f_{bcD} \ge -0.6 \cdot f_{c'}, 1, 0\right) = 1$$

*Tension Check*

$$Ck_{D.b.tens} := \text{if}\left(f_{btD} \le 6 \cdot \sqrt{\frac{f_{c'}}{psi}} \cdot psi \wedge f_{btD} \ge -0.6 \cdot f_{c'}, 1, 0\right) = 1$$

*Check for stress at deck placement condition*

$$Ck_{stress.deck} := \text{if}\left(\min\left(Ck_{D.t.comp}, Ck_{D.t.tens}, Ck_{D.b.comp}, Ck_{D.b.tens}\right) = 1, \text{"OK"}, \text{"Not OK"}\right) = \text{"OK"}$$

## Roll Stability Check during Deck Placement:

*Lateral Cracking Moment*

$$M_{latD} := \min\left[\frac{\left(f_r - f_{ttD}\right) \cdot I_y}{.5 \cdot b_t}, \frac{\left(f_r - f_{btD}\right) \cdot I_y}{.5 \cdot b_b}\right] = 1.259 \times 10^4 \cdot kip \cdot in$$

*Y-direction moment that causes cracking*

*Rotation Angle at Cracking*

$$\theta_{crD} := \frac{M_{latD}}{M_{gD}} = 0.114 \cdot rad$$

*Initial Rotation*

$$\theta_{i.D} := \frac{\alpha \cdot r + e_s}{r - y - z_o} + \frac{\min\left(e_b, e_{wD}\right)}{y} = 0.019$$

*Torque due to construction live loads*

$$T_D := \left(.5 \cdot w_{fm} + P_l \cdot L_b\right) \cdot \left(OH + d_{fm}\right) = 46.681 \cdot kip \cdot ft$$

*Twist due to construction live loads*

$$\phi_D := \frac{T_D \cdot .5 \cdot L_b}{G_{shear} \cdot J} = 0.0031$$

*Deflection at cantilever due to twist*

$$\delta_D := OH \cdot \tan\left(\phi_D\right) = 0.112 \cdot in$$

*Total Rotation*

$$\theta_D := \theta_{i.D} + \phi_D = 0.022$$

*Rotation Limits*

$$\theta_{D.max} := \min\left(\theta_{crD}, 5 \cdot deg\right) = 0.087$$

*Deck Placement Rotation Check*

$$Ck_{stab.deck} := \text{if}\left(\delta_D \le \delta_{max} \wedge \theta_D \le \theta_{D.max}, \text{"OK"}, \text{"Not OK"}\right) = \text{"OK"}$$

*The initial rotation is caused by the imperfections in the girder and girder support. Additionally, it can be expected that the construction loads will cause the maximum "play" in the bracing to be achieved, which results in an eccentricity of $e_b$. The initial rotation is the maximum rotation that is seen at the bracing points. Any additional rotation is between the bracing points in the form of torque. The torque is caused by the construction live loads acting on the overhang of the bridge, eccentric to the centerline of the exterior girder.*

## Bracing Requirements:

*Factored Horizontal Force at Each Beam End and Anchor Brace, at midheight of beam*

$F_e := w_w \cdot \gamma \cdot h \cdot L_b \cdot K_{ve} = 8.69 \cdot kip$

*Factored Horizontal Bracing Force at Each Intermediate SpanBrace (if present), at mid-height of beam*

$F_i := if\left(n_b = 0, "N/A", w_w \cdot \gamma \cdot h \cdot L_b \cdot K_{vi}\right) = 23.898 \cdot kip$

*Factored Overturning Force at Each Beam End and Anchor Brace, at top of beam*

$$M_e := M_{fm} + M_c \cdot L_b \cdot K_{ve} + w_{wD} \cdot \gamma \cdot h \cdot L_b \cdot K_{ve} \cdot .5 \cdot h - .9 \cdot w \cdot L_b \cdot \left[\frac{b_b}{2} - \left(z_o \cdot \theta_{i.D} + e_s + \min\left(e_b, e_{wD}\right) + y \cdot \theta_{i.D}\right)\right] \cdot K_{ve} = 27.31 \cdot kip \cdot ft$$

*Factored Overturning Force at Each Intermediate Span Brace (if present), at top of beam*

$$M_i := M_{fm} + M_c \cdot L_b \cdot K_{vi} + w_{wD} \cdot \gamma \cdot h \cdot L_b \cdot K_{vi} \cdot .5 \cdot h - .9 \cdot w \cdot L_b \cdot \left[\frac{b_b}{2} - \left(z_o \cdot \theta_{i.D} + e_s + \min\left(e_b, e_{wD}\right) + y \cdot \theta_{i.D}\right)\right] \cdot K_{ve} = 63.747 \cdot kip \cdot ft$$

---

## Verification of Bracing Adequacy

*Stress Checks*

$Ck_{stress.plcmnt}$ = "OK"

$Ck_{stress.braced}$ = "OK"

$Ck_{stress.deck}$ = "OK"

*Stability Checks*

$Ck_{stab.plcmnt}$ = "OK"

*If $Ck_{stab.plcmnt}$ is "Not OK," the girder must be braced prior to crane release.*

$Ck_{stab.braced}$ = "OK"

$Ck_{stab.deck}$ = "OK"

## Temporary Bracing Variables

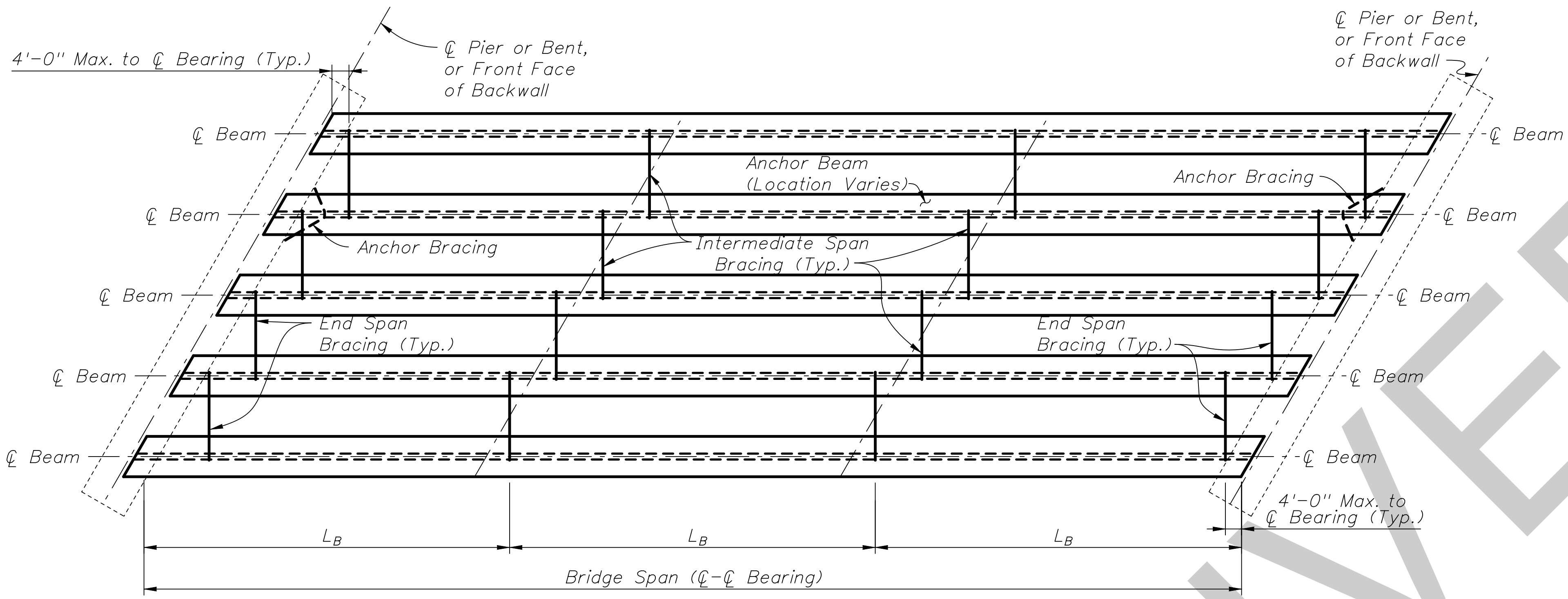
| | |
|---|---|
| *Maximum Un-braced Length* | $L_b = 60.667\,ft$ |
| *Factored Horizontal Force at Each Beam End and Anchor Brace, at mid-height of beam* | $F_e = 8.69 \cdot kip$ |
| *Factored Horizontal Bracing Force at Each Intermediate SpanBrace (if present), at mid-height of beam* | $F_i = 23.898 \cdot kip$ |
| *Factored Overturning Force at Each Beam End and Anchor Brace, at top of beam* | $M_e = 27.31 \cdot kip \cdot ft$ |
| *Factored Overturning Force at Each Intermediate Span Brace (if present), at top of beam* | $M_i = 63.747 \cdot kip \cdot ft$ |

## Wind Load Variables

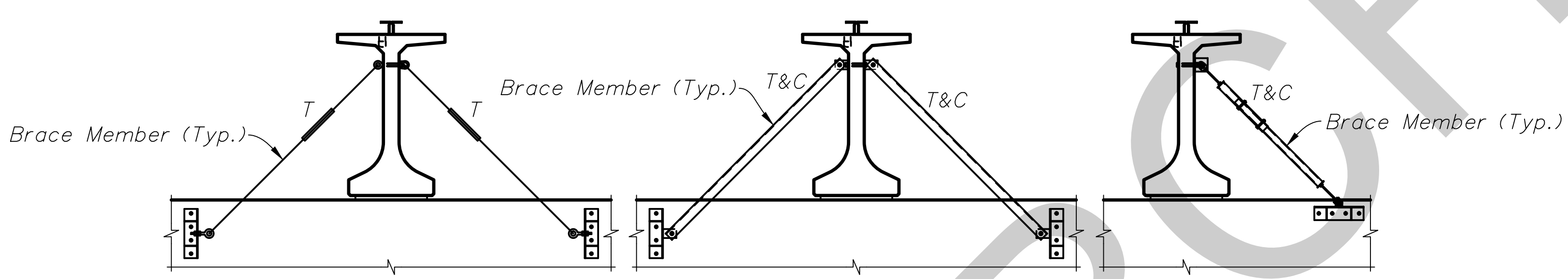
| | |
|---|---|
| *Basic Wind Speed* | $V_B = 150 \cdot mph$ |
| *Construction Inactive Wind Speed* | $V = 90 \cdot mph$ |
| *Construction Active Wind Speed* | $V_E = 20 \cdot mph$ |
| *Velocity Pressure Exposure Coefficient* | $K_z = 1.137$ |
| *Gust effect factor* | $G = 0.85$ |

## Assumed Construction Loads

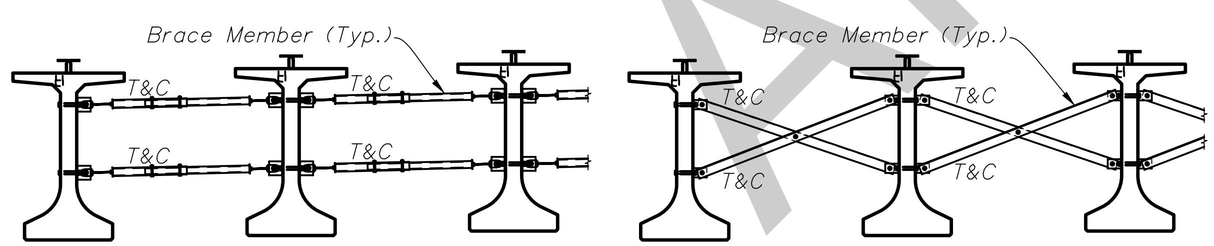
| | |
|---|---|
| *Weight of build-up* | $w_b = 50 \cdot plf$ |
| *Form Weight* | $w_f = 20 \cdot psf$ |
| *Finishing Machine Total Weight* | $w_{fm} = 20 \cdot kip$ |
| *Finishing Machine Wheel Location Beyond Edge of Deck Overhang* | $d_{fm} = 2.5 \cdot in$ |
| *Deck Weight* | $w_d = 113.333 \cdot psf$ |
| *Live load* | $w_l = 20 \cdot psf$ |
| *Live Load at Extreme Deck Edge* | $P_l = 75 \cdot plf$ |




## PRESTRESSED BEAM TEMPORARY BRACING PLAN VIEW
(Skewed Condition Shown, Non-skewed Condition Similar)




## EXAMPLE ANCHOR BRACING TYPICAL SECTIONS
(Beam Ends Only)




## EXAMPLE END SPAN/INTERMEDIATE BRACING TYPICAL SECTIONS

NOTES:

1. The 'PRESTRESSED BEAM TEMPORARY BRACING PLAN' is to be used in conjunction with the 'TABLE OF TEMPORARY BRACING VARIABLES' in the Structures Plans. The brace locations and quantities shown in the plan view are schematic only, and the actual brace locations and quantities should be determined from the 'TABLE OF TEMPORARY BRACING VARIABLES' in the Structures Plans.

2. The bracing members shown in the sections are schematic only, and are meant to show geometry in which bracing should be placed. The bracing members and connections shall be designed and detailed by the Contractor. Any of the geometric configurations shown in the bracing sections are acceptable. The bracing may be attached through the web or to the flanges of the beam, as necessary. The bracing shall be positively and securely connected to each beam, and shall not be designed to exert any vertical force on the outer edge of the top flange. All bolt holes in beams are to be preformed and filled after use. All bracing is to be placed perpendicular to beams.

3. The anchor beam is a beam which has anchor bracing at its support locations. It is to be set first, and its location may vary. All subsequent beams are to be braced against the Anchor Beam sequentially. The Anchor brace may be located at an exterior girder provided that all required bolt clear distances are met and overhang bracing is not impacted. Anchor bracing may be inclined, as shown in the plan view, or may be installed vertically.

4. Overhang bracing requirements are neither specified here nor in the 'TABLE OF TEMPORARY BRACING VARIABLES.' It is the Contractor's responsibility to design overhang bracing which does not cause excessive deflection or rotation of the exterior girder, or cause the girder stresses to exceed stress limits per the FDOT Structures Manual.

5. The Contractor shall submit documentation required by the Specifications for Road and Bridge Construction, Section 5 for 'Beam and Girder Temporary Bracing.' If the Contractor elects to use the bracing requirements shown in the 'TABLE OF TEMPORARY BRACING VARIABLES,' the documentation shall include signed and sealed certification that the construction loads do not exceed those shown in the 'TABLE OF ASSUMED CONSTRUCTION LOADS' and signed and sealed design of bracing members and connections. If the Contractor elects to use a bracing scheme different from those shown in the 'TABLE OF TEMPORARY BRACING VARIABLES,' the documentation shall include signed and sealed calculation of the bracing requirements and design of bracing members and connections.

LEGEND:

T = Tension Member
T&C = Tension & Compression Member

STRUCTURES DESIGN BULLETIN C10-01
ATTACHMENT 'B'

REVISIONS

| DATE | BY | DESCRIPTION | DATE | BY | DESCRIPTION |
|---|---|---|---|---|---|
| 01/01/10 | SJN | New Design Standard | | | |

STATE OF FLORIDA DEPARTMENT OF TRANSPORTATION

2010 FDOT Design Standards

# PRESTRESSED BEAM TEMPORARY BRACING

Last Revision 01/01/10

Sheet No. 1 of 1

Index No. 20005

INSTRUCTIONAL NOTES TO DESIGNERS

## GENERAL INSTRUCTIONS:

The Standard Drawings for prestressed beam bracing (Index No. 20005) depict notes and details that are schematic for use in the development of beam bracing shop drawings. These drawings and notes are included in the contract documents by reference to the Index No. in the plans. Companion MicroStation CADD cell 20005, which includes the 'TABLE OF TEMPORARY BRACING VARIABLES,' the 'TABLE OF WIND LOAD VARIABLES,' the 'TABLE OF ASSUMED CONSTRUCTION LOADS,' and the 'BEAM TEMPORARY BRACING NOTES'. The tables are to be completed and included in the plans with the note.

The FDOT Beam Stability MathCAD program may be used to determine the variables to be input into the 'TABLE OF TEMPORARY BRACING VARIABLES,' the 'TABLE OF WIND LOAD VARIABLES,' and the 'TABLE OF ASSUMED CONSTRUCTION LOADS.'

The forces that are entered into the columns for beam end and intermediate horizontal bracing forces in the 'TABLE OF TEMPORARY BRACING VARIABLES,' shall be the horizontal reaction forces at each brace point. Forces should not be resolved into a diagonal component, regardless of any inclination of the actual bracing. These forces are to be used by the Contractor to design bracing members and connections.

The assumed weight for the finishing machine is left to the discretion of the EOR, but suggested total weights for the finishing machine are 10 kips for bridge widths less than 45 feet and 20 kips otherwise.

If intermediate span braces are not required, enter "N/A" in the horizontal and overturning force columns for each span for which intermediate span braces are not required.

EXAMPLE PROBLEM

The following example shows the data required for completion of the Data Table for the Prestressed Beam Temporary Bracing Index No. 20005. This case shows a Florida-I 78 Beam (Index No. 20078).

The example assumes a three equal span bridge designed for the following conditions:

Girder Span: 182'-0"
Girder Spacing: 6'-0"
Number of Girder Lines: 7
Deck Thickness: 8½"
Deck Overhang: 3'-0"
Skew Angle: 45°
Bridge Height: 60'-0"
Construction Inactive Wind Load: 44.0 psf (150 mph reduced by 0.6 to 90 mph)
Construction Active Wind Load (20 MPH): 2.2 psf (girder only), 1.1 psf (bridge with forms in place)

Based on beam stability calculations, (1) intermediate brace point would be sufficient, but the bracing force would be very large. Therefore, the bracing requirements will be calculated based on (2) intermediate brace points.

The maximum unbraced length is: 182'-0"/3 = 60'-8"

| TABLE OF WIND LOAD VARIABLES | Table Date 1-01-10 |
|---|---|
| WIND SPEED, BASIC (MPH) | 150 |
| WIND SPEED, CONSTRUCTION INACTIVE (MPH) | 90 |
| WIND SPEED, CONSTRUCTION ACTIVE (MPH) | 20 |
| VELOCITY PRESSURE EXPOSURE COEFFICIENT | 1.137 |
| GUST EFFECT FACTOR | 0.85 |

| TABLE OF ASSUMED CONSTRUCTION LOADS (UNFACTORED) | Table Date 1-01-10 |
|---|---|
| BUILD-UP (PLF) | 50 |
| FORM WEIGHT (PSF) | 20 |
| FINISHING MACHINE TOTAL WEIGHT (KIP) | 20 |
| FINISHING MACHINE WHEEL LOCATION BEYOND EDGE OF DECK OVERHANG (IN.) | 2½ |
| DECK WEIGHT (PSF) | 113.3 |
| LIVE LOAD (PSF) | 20 |
| LIVE LOAD AT EXTREME DECK EDGE (PLF) | 75 |

TABLE OF TEMPORARY BRACING VARIABLES (Table Date 1-01-10)

| SPAN NO. | $L_B$, MAXIMUM UNBRACED LENGTH (FT) | HORIZONTAL FORCE AT EACH BEAM END AND ANCHOR BRACE (KIP) | HORIZONTAL FORCE AT EACH INTERMEDIATE SPAN BRACE (KIP) | OVERTURNING FORCE AT EACH BEAM END AND ANCHOR BRACE (KIPxFT) | OVERTURNING FORCE AT EACH INTERMEDIATE SPAN BRACE (KIPxFT) | BRACE ENDS PRIOR TO CRANE RELEASE? | TOTAL NUMBER OF BRACES |
|---|---|---|---|---|---|---|---|
| 1 | 60.67 | 8.69 | 23.90 | 27.31 | 63.75 | NO | 24 |
| 2 | 60.67 | 8.69 | 23.90 | 27.31 | 63.75 | NO | 24 |
| 3 | 60.67 | 8.69 | 23.90 | 27.31 | 63.75 | NO | 24 |

BEAM TEMPORARY BRACING NOTES:

Based on investigation of the beam stability, temporary bracing as shown in the 'TABLE OF TEMPORARY BRACING VARIABLES' and Design Standard Index No. 20005 is required. The Table and following information is provided to aid the Contractor in design of beam temporary bracing:

1. Design the bracing members and connections to transfer both compressive and tensile forces equal to the horizontal forces given in the 'TABLE OF TEMPORARY BRACING VARIABLES'. Also design bracing members and connections to be capable of resisting the overturning forces given in the Table, non-simultaneously with horizontal forces. Assume that horizontal bracing forces are applied perpendicular to the beam web at mid-height of the beam, and assume that overturning bracing forces are applied at the centerline of the beam at the top of the top flange.
2. The horizontal brace forces have been determined by application of the Construction Inactive Wind Load as listed in the 'TABLE OF WIND LOAD VARIABLES'. The overturning brace forces have been determined by application of the Construction Active Wind Load as listed in the 'TABLE OF WIND LOAD VARIABLES' plus the assumed construction loads shown in the 'TABLE OF ASSUMED CONSTRUCTION LOADS'. It is the Contractor's responsibility to re-calculate the bracing requirements if the actual construction loads exceed the assumed loads shown, or if the finishing machine wheel location from the edge of the deck overhang exceeds the value listed.
3. The temporary bracing at the ends of the beams shall be installed prior to crane release if indicated in the 'TABLE OF TEMPORARY BRACING VARIABLES'. Beams shall not be left un-braced during non-work hours. Bracing at the ends of the beams shall remain in place until the diaphragm concrete reaches 2500 psi. The temporary intermediate bracing, if required, shall remain in place until bridge deck concrete reaches 2500 psi.
4. The exposure period (defined as the time period for which temporary load cases of the superstructure exist) is assumed to be less than one year. Horizontal bracing forces, as specified in the 'TABLE OF TEMPORARY BRACING VARIABLES', are not valid if the exposure period is more than one year; for this case the Contractor shall re-calculate bracing requirements.
5. Horizontal and overturning forces are factored per the Strength III limit state for construction.

# PRESTRESSED BEAM TEMPORARY BRACING DATA TABLES

| TABLE OF WIND LOAD VARIABLES | Table Date 1-01-10 |
|---|---|
| WIND SPEED, BASIC (MPH) | |
| WIND SPEED, CONSTRUCTION INACTIVE (MPH) | |
| WIND SPEED, CONSTRUCTION ACTIVE (MPH) | |
| VELOCITY PRESSURE EXPOSURE COEFFICIENT | |
| GUST EFFECT FACTOR | |

| TABLE OF ASSUMED CONSTRUCTION LOADS (UNFACTORED) | Table Date 1-01-10 |
|---|---|
| BUILD-UP (PLF) | |
| FORM WEIGHT (PSF) | |
| FINISHING MACHINE TOTAL WEIGHT (KIP) | |
| FINISHING MACHINE WHEEL LOCATION BEYOND EDGE OF DECK OVERHANG (IN.) | |
| DECK WEIGHT (PSF) | |
| LIVE LOAD (PSF) | |
| LIVE LOAD AT EXTREME DECK EDGE (PLF) | |

| TABLE OF TEMPORARY BRACING VARIABLES | | | | | | | Table Date 1-01-10 |
|---|---|---|---|---|---|---|---|
| SPAN NO. | $L_B$, MAXIMUM UNBRACED LENGTH (FT) | HORIZONTAL FORCE AT EACH BEAM END AND ANCHOR BRACE (KIP) | HORIZONTAL FORCE AT EACH INTERMEDIATE SPAN BRACE (KIP) | OVERTURNING FORCE AT EACH BEAM END AND ANCHOR BRACE (KIPxFT) | OVERTURNING FORCE AT EACH INTERMEDIATE SPAN BRACE (KIPxFT) | BRACE ENDS PRIOR TO CRANE RELEASE? | TOTAL NUMBER OF BRACES |
| | | | | | | YES/NO | |
| | | | | | | YES/NO | |
| | | | | | | YES/NO | |
| | | | | | | YES/NO | |

BEAM TEMPORARY BRACING NOTES:

Based on investigation of the beam stability, temporary bracing as shown in the 'TABLE OF TEMPORARY BRACING VARIABLES' and Design Standard Index No. 20005 is required. The Table and following information is provided to aid the Contractor in design of beam temporary bracing:

1. Design the bracing members and connections to transfer both compressive and tensile forces equal to the horizontal forces given in the 'TABLE OF TEMPORARY BRACING VARIABLES'. Also design bracing members and connections to be capable of resisting the overturning forces given in the Table, non-simultaneously with horizontal forces. Assume that horizontal bracing forces are applied perpendicular to the beam web at mid-height of the beam, and assume that overturning bracing forces are applied at the centerline of the beam at the top of the top flange.
2. The horizontal brace forces have been determined by application of the Construction Inactive Wind Load as listed in the 'TABLE OF WIND LOAD VARIABLES'. The overturning brace forces have been determined by application of the Construction Active Wind Load as listed in the 'TABLE OF WIND LOAD VARIABLES' plus the assumed construction loads shown in the 'TABLE OF ASSUMED CONSTRUCTION LOADS'. It is the Contractor's responsibility to re-calculate the bracing requirements if the actual construction loads exceed the assumed loads shown, or if the finishing machine wheel location from the edge of the deck overhang exceeds the value listed.
3. The temporary bracing at the ends of the beams shall be installed prior to crane release if indicated in the 'TABLE OF TEMPORARY BRACING VARIABLES'. Beams shall not be left un-braced during non-work hours. Bracing at the ends of the beams shall remain in place until the diaphragm concrete reaches 2500 psi. The temporary intermediate bracing, if required, shall remain in place until bridge deck concrete reaches 2500 psi.
4. The exposure period (defined as the time period for which temporary load cases of the superstructure exist) is assumed to be less than one year. Horizontal bracing forces, as specified in the 'TABLE OF TEMPORARY BRACING VARIABLES', are not valid if the exposure period is more than one year; for this case the Contractor shall re-calculate bracing requirements.
5. Horizontal and overturning forces are factored per the Strength III limit state for construction.