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Steel Superstructures

Presented By: Michael L. McCool, Jr., PE

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Design for Constructability

Introduction

The use of higher strength steels in obtaining such long spans creates the need for designers to consider additional aspects associated with the construction of the bridge.

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Design for Constructability

Introduction

Many times the critical stress in a particular component is encountered during the erection of the bridge where large unbraced lengths affect the stability of the partially completed structure.

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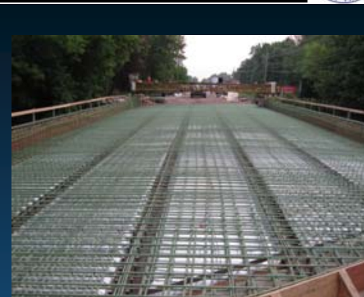
Design for Constructability



Construction Loads

The AASHTO *LRFD Bridge Design Specifications* do not completely address the loadings that should be considered during construction of steel bridges.

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Construction Loads

Some general statements are provided saying that investigations should be made for handling, transportation and erection, but no quantification is given.

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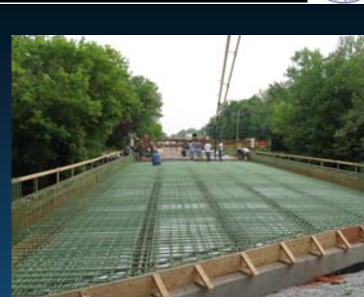
Design for Constructability



Construction Loads

Some guidance is provided for the application of load factors for dead loads, dynamic effects (impact) and wind, but specific load combinations are not explicitly defined.

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INDIANA DEPARTMENT OF TRANSPORTATION
Driving Indiana's Economic Growth

Design Memorandum No. 10-18
Policy Change

July 9, 2010

TO: All Design, Operations, and District Personnel, and Consultants

FROM: /s/ Anthony L. Uremovich
Anthony L. Uremovich
Design Resources Engineer
Production Management Division

SUBJECT Bridge Construction-Loads Considerations

ADDS *Indiana Design Manual* Section 60-3.10

EFFECTIVE: October 1, 2010 Stage 3 Submission

Construction loadings shall be evaluated in accordance with AASHTO *LRFD* Article 3.4.2. Article 3.4.2.1 addresses evaluation at the Strength Limit State. Article 3.4.2.2 addresses the evaluation of deflections at the Service Limit State.

Construction loadings are typically not accurately known during the design stage. As a minimum, the values listed in Figure 10-18A or 10-18B, Construction Loading, shown below, should be used. However, these values may be increased if information supporting increased construction loads is available during the design stage. The source of this information should be documented in the design calculations. The magnitude and location of the assumed construction loadings used for design should be shown in the contract documents.

For a beam or girder structure, the information shown in Figure 10-18A for an english-units project (Figure 10-18B for a metric-units project) should be shown on the General Plan. If increased loads are permitted, the appropriate values in the figure should be changed accordingly. The exterior beam or girder should be checked for the specified construction loadings.

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PDF versions of the required information to be incorporated onto the General Plan sheet are attached herewith.

CONSTRUCTION LOADING

The exterior girder has been checked for strength, deflection, and overturning using the constructions loads shown below. Cantilever overhang brackets were assumed for support of the deck overhang past the edge of the exterior girder. The finishing machine was assumed to be supported 6 in. outside the vertical coping form. The top overhang brackets were assumed to be located 6 in. past the edge of the vertical coping form. The bottom overhang brackets were assumed to be braced against the intersection of the girder bottom flange and web.

Deck Falsework Loads: Designed for 15 lb/ft^2 for permanent metal stay-in-place deck forms, removable deck forms, and 2-ft exterior walkway.

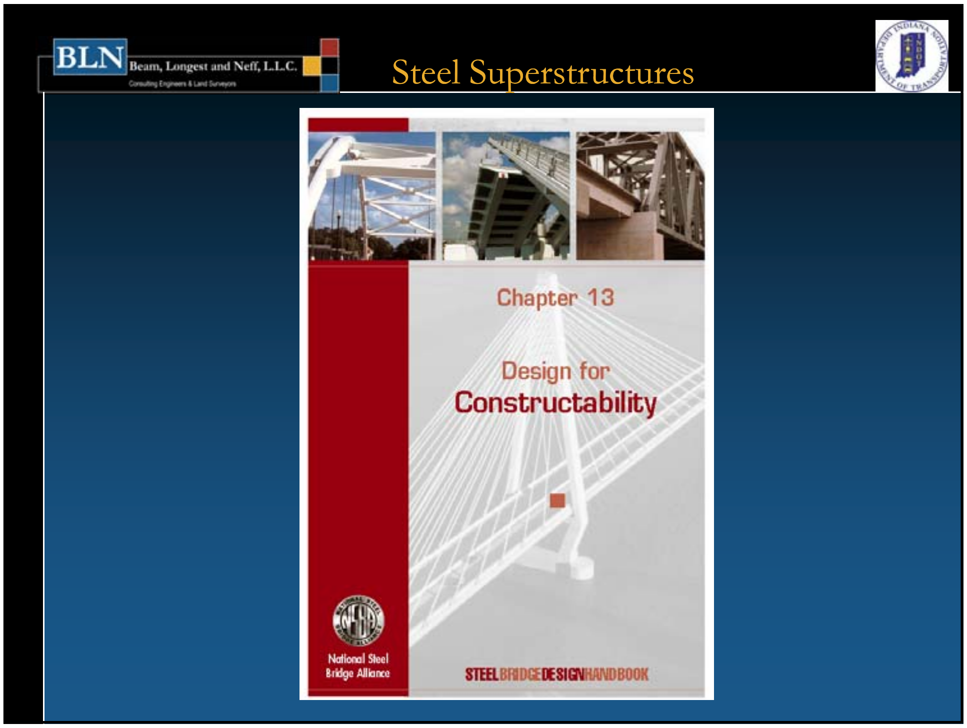
Construction Live Load: Designed for 20 lb/ft^2 extending 2 ft past the edge of coping and 75 lb/ft vertical force applied at a distance of 6 in. outside the face of coping over a 30-ft length of the deck centered with the finishing machine.

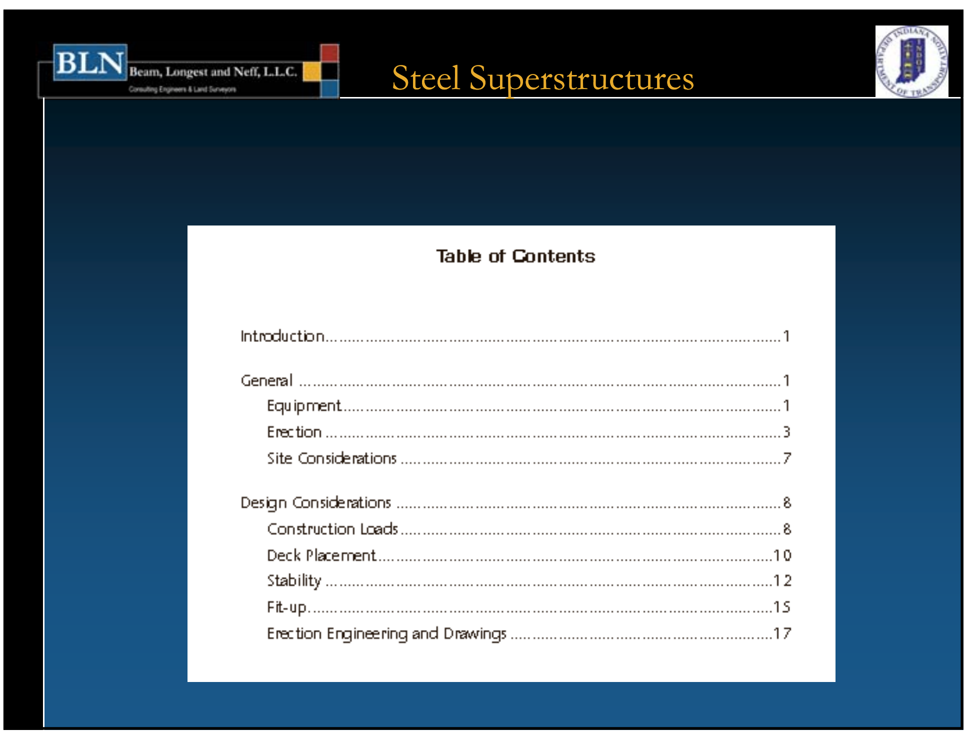
Finishing-Machine Load: 4500 lb distributed over 10 ft along the coping.

Wind Load: Designed for 70 mph horizontal wind loading of 50 lb/ft^2 in accordance with AASHTO *Guide Design Specifications for Bridge Temporary Works* (1995), Figure 2.1.

CONSTRUCTION-LOADINGS INFORMATION TO BE SHOWN ON GENERAL PLAN, ENGLISH-UNITS PROJECT

Figure 10-18A





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AASHTO Section 2: General Design and Location Features

2.5.3 Constructability

Constructability issues should include, but not be limited to, consideration of *deflection, strength* of steel and concrete, and *stability* during *critical stages* of construction.

Bridges should be designed in a manner such that fabrication and erection can be performed without undue difficulty or distress and that locked-in construction force effects are within tolerable limits.

When the designer has assumed a *particular sequence* of construction in order to induce certain stresses under dead load, that sequence shall be defined in the contract documents.

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AASHTO Section 3: Loads and Load Factors

3.4.2 Load Factors for Construction Loads
3.4.2.1 Evaluation at the Strength Limit State

All appropriate strength load combinations in Table 3.4.1-1, modified as specified herein, shall be investigated.

When investigating *Strength Load Combinations I, III, and V* during construction, load factors for the weight of the structure and appurtenances, *DC* and *DW*, shall not be taken to be less than 1.25.

Unless otherwise specified by the Owner, the load factor for construction loads and for any associated dynamic effects shall not be less than 1.5 in Strength Load Combination I. The load factor for wind in Strength Load Combination III shall not be less than 1.25.

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AASHTO Section 3: Loads and Load Factors

C3.4.2.1

The load factors presented here *should not relieve the contractor of responsibility for safety and damage control during construction.*

Construction loads are permanent loads and other loads that act on the structure only during construction. Construction loads include the *weight of equipment such as deck finishing machines* or loads applied to the structure through falsework or other temporary supports. Often the construction loads are not *accurately known at design time*; however, the magnitude and location of these loads considered in the design should be *noted on the contract documents*.

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AASHTO Section 3: Loads and Load Factors

3.4.2.2 Evaluation of Deflection at the Service Limit State

In the absence of special provisions to the contrary, where evaluation of construction *deflections* are required by the contract documents, *Load Combination Service I* shall apply. Construction dead loads shall be considered as part of the permanent load and construction transient loads considered part of the live load. The associated permitted deflections shall be included in the contract documents.

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Design for Constructability

Deck Placement

Typically, the most critical stage in the construction of girder bridges occurs during placement of the concrete deck, since the bridge is being loaded with the majority of its dead load while only discrete bracing stabilizes the most vulnerable top compression flange components.

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Design for Constructability

Construction Loads

Construction live loads **should be considered in evaluating the adequacy of the bridge. This loading is intended to cover all miscellaneous equipment and personnel that cannot easily be quantified at the time of design.**

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Design for Constructability

Construction Loads

Wind loads during construction can be one of the most critical aspects to evaluate for conventional girder bridges, since the concrete deck is typically used to transmit these force effects back to the support locations.

AASHTO's *Guide Design Specifications for Bridge Temporary Works.*

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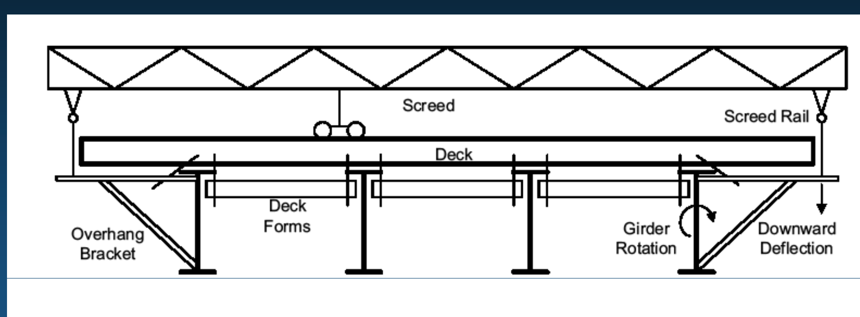

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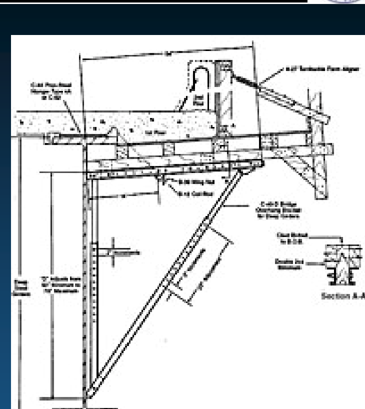
Design for Constructability

Deck Placement

Overhang brackets are typically used to support deck forms in the area beyond the edges of the fascia girders. The overhang brackets can create significant lateral flange bending forces in the top and bottom flanges of the fascia girder due to the eccentricity of the loads and the hanger connection to the flange.



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Design for Constructability

Stability

Stability of the girders during erection and subsequent construction stages is of primary importance to the designer since it is typically the driving factor in the selection of crossframe spacing's, top flange width and lateral bracing requirements.

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Construction Plan Notes

Design Data

CONSTRUCTION LOADING

The exterior girder has been checked for strength, deflection and overturning using the construction loads shown below. Cantilever overhang brackets were assumed for support of the deck overhang past the edge of the exterior girder. The finishing machine was assumed to be supported 6 inches outside the vertical coping form. The top overhang brackets were assumed to be located 6 inches past the edge of the vertical coping form. The bottom overhang brackets were assumed to be braced against the intersection of the girder bottom flange and web.

DECK FALSEWORK LOADS: Designed for 15 psf for permanent metal stay–in–place deck forms, removable deck forms and 2' exterior walkway.

CONSTRUCTION LIVE LOAD: Designed for 20 psf Construction Live Load extending 2' past the edge of coping and 75 PLF vertical force applied at a distance of 6 inches outside the face of coping over a 30 foot deck area centered with the finishing machine.

FINISHING MACHINE LOAD: 4500 lbs distributed over 10 feet along the coping.

WIND LOAD: Designed for 70 mph horizontal wind loading (50 psf) in accordance with A.A.S.H.T.O. Guide Design Specifications (1995) for Bridge Temporary Works Fig 2.1

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Construction Loads

Loads during construction are:

DC = Dead Load from Bridge Members, Formwork, Deck, etc.

- **DC1 – Concrete = 150 lbs/ft^3**
- **DC2 – Stay-in-place Formwork = 15 psf**

DW = N/A for Non-Composite Construction

CDL = Construction Equipment loads such as screed rails, overhang forms, temp railing, walkway

- **CDL1 – Removable Coping Deck Forms = 15 psf**
- **CDL2 – Temporary Walkway = 15 psf – applied over a 2'-0" wide platform on outside of coping**

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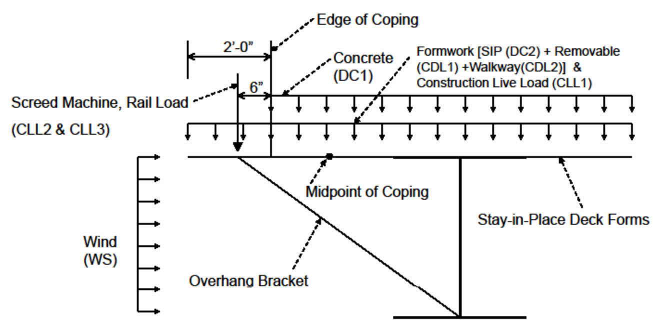

FIGURE 1

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Construction Loads

Loads during construction are:

CLL = Construction Live Load such as Screed Machine and Workers

- CLL1 – Construction Live Load = 20 psf extended the entire bridge width plus two feet outside of bridge coping over 30 feet longitudinal length centered on Screed Machine Load
- CLL2 –Screed Machine = 4500 lbs over 10 feet longitudinal length applied 6 in outside of bridge coping.
- CLL3 – Vertical Railing and Walkway Load = 75 plf applied 6 in outside of bridge coping over 30 feet longitudinal length centered on Screed Machine Load

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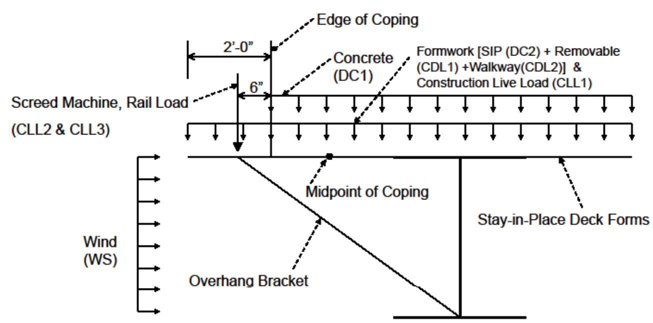

FIGURE 1

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Construction Loads

Loads during construction are:

WS = Wind Load on exposed height of the Structure (negligible for interior girders)

- **WS - Calculated per AASHTO 3.8.1.1 (use 70 mph per AASHTO Temporary works manual Fig 2.1.**

WCEL = Wind Load on screed machine (negligible)

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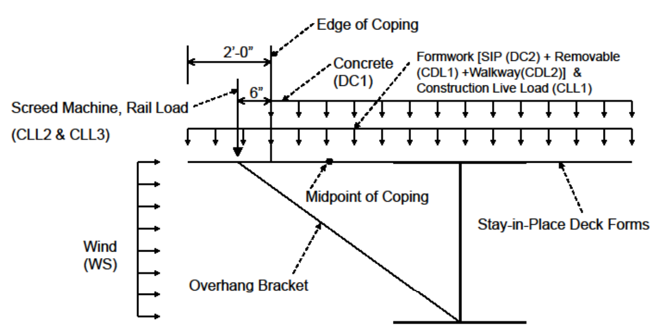
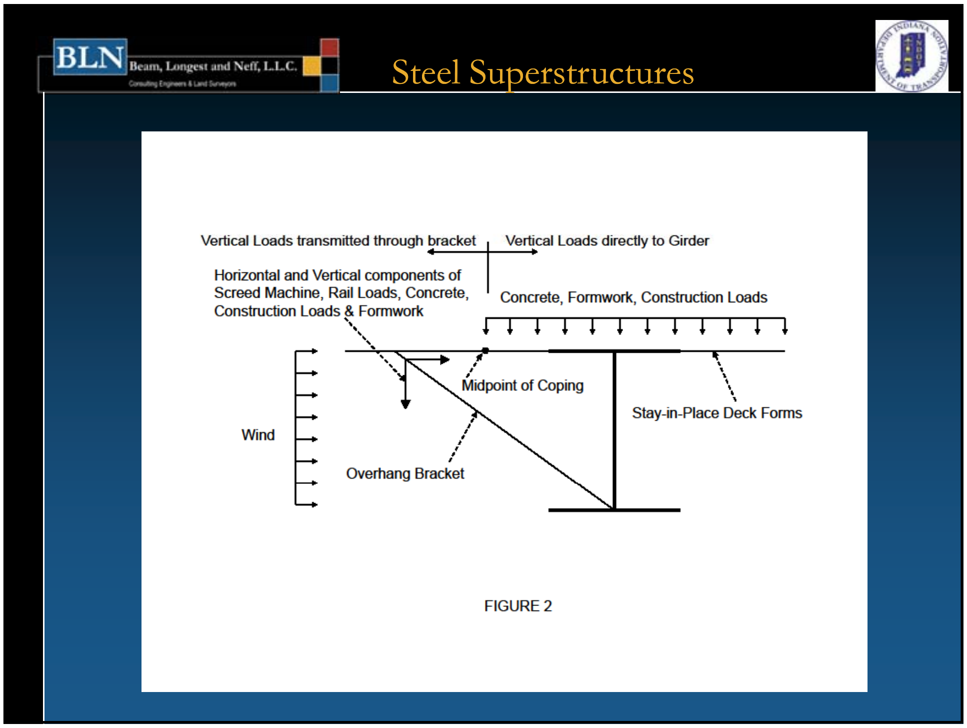


FIGURE 1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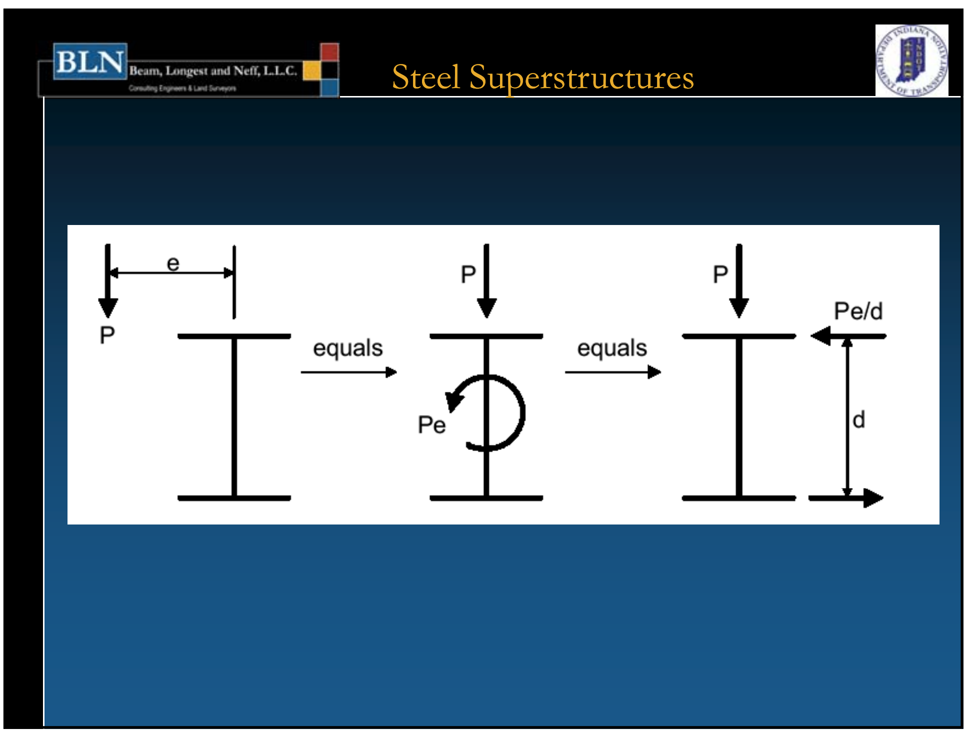
Vertical Loads transmitted through bracket
Vertical Loads directly to Girder
Horizontal and Vertical components of Screed Machine, Rail Loads, Concrete, Construction Loads & Formwork
Concrete, Formwork, Construction Loads
Midpoint of Coping
Stay-in-Place Deck Forms
Wind
Overhang Bracket
FIGURE 2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Load Factors

Load Combinations in accordance with AASHTO 3.4.2.1 and 3.4.2.2:

STRENGTH I - 1.25(DC + DW) + 1.5(CDL + CLL)

STRENGTH III - 1.25(DC + DW) + 1.5(CDL) + 1.25(WS)

STRENGTH IV - 1.5(DC + DW) + 1.5(CDL)

STRENGTH V - 1.25(DC+DW)+1.5(CDL)+1.35(CLL)+0.4(WS)

SERVICE I - 1.0(DC+DW)+1.0(CDL)+1.0(CLL) +0.3(WS)

SERVICE II - 1.0(DC+DW)+1.0(CDL)+1.3(CLL)

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AASHTO Section 6: Steel Structures

6.10.3 Constructibility
6.10.3.1 General

The provisions of Article 2.5.3 shall apply. In addition to providing adequate strength, nominal yielding or reliance on post-buckling resistance shall not be permitted for main load-carrying members during critical stages of construction, except for yielding of the web in hybrid sections. This shall be accomplished by satisfying the requirements of Articles 6.10.3.2 and 6.10.3.3 at each ***critical construction stage***. For sections in positive flexure that are composite in the final condition, but are noncomposite during construction, the provisions of Article 6.10.3.4 shall apply. For investigating the ***constructability of flexural members, all loads shall be factored as specified in Article 3.4.2***. For the calculation of ***deflections***, the load factors shall be taken as 1.0.

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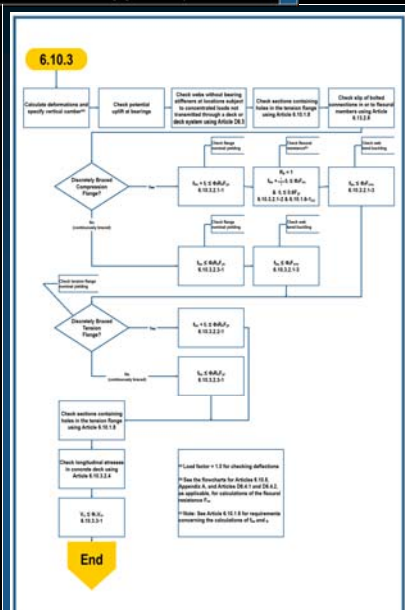

AASHTO Figure C6.4.1-1

Constructability

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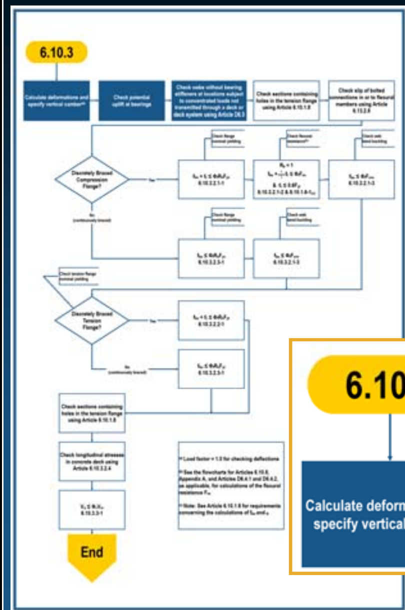
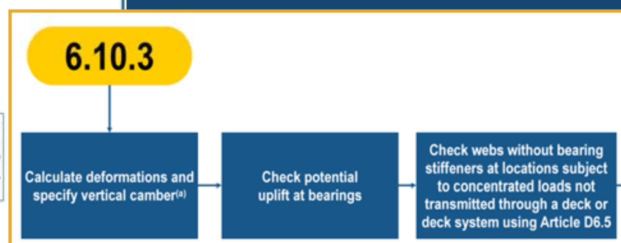


Deflections

Construction deflections are for Dead Load only.

Deflection < L/240

AASHTO's *Guide Design Specifications for Bridge Temporary Works.*



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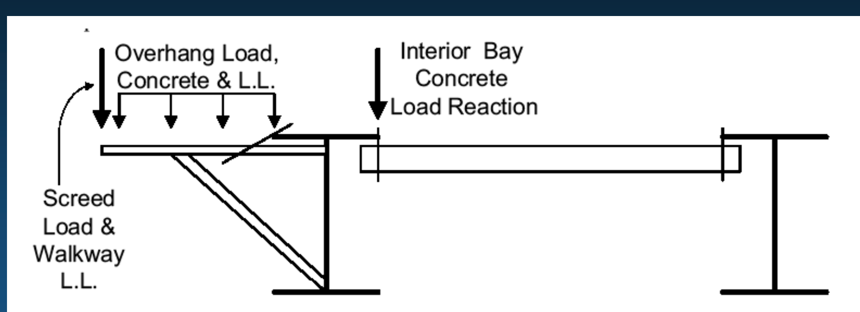

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Limit States

Lateral Girder Rotation Check

This check ensures excessive overhang deflections do not occur during the deck pour which can adversely affect the finished grades. (Deflection @ Screed Rail < 0.2 in)

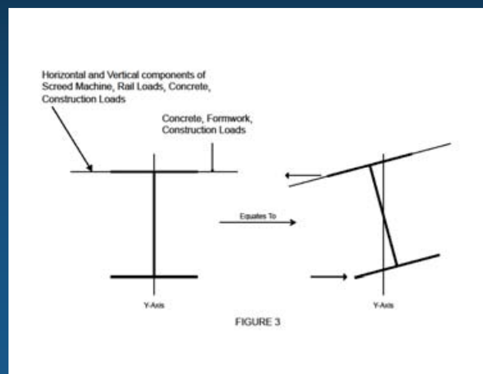

FIGURE 3

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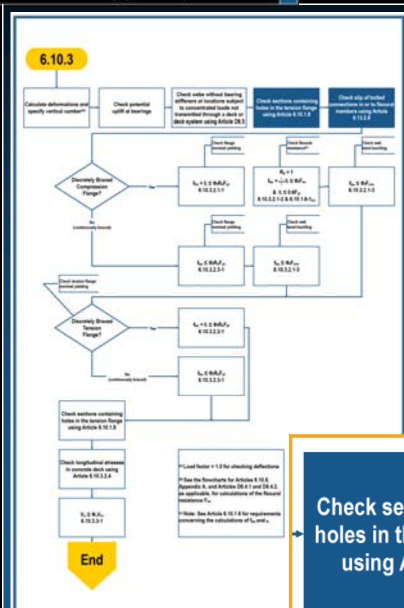

Check sections containing holes in the tension flange using Article 6.10.1.8

Check slip of bolted connections in or to flexural members using Article 6.13.2.8

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Limit States

Diaphragm Slip Critical Bolt Check

This check ensures that the connection used to attach the diaphragms to the webs of the steel members is adequate to resist the moment caused by the lateral rotation of the girder and horizontal force caused by the overhang bracket.

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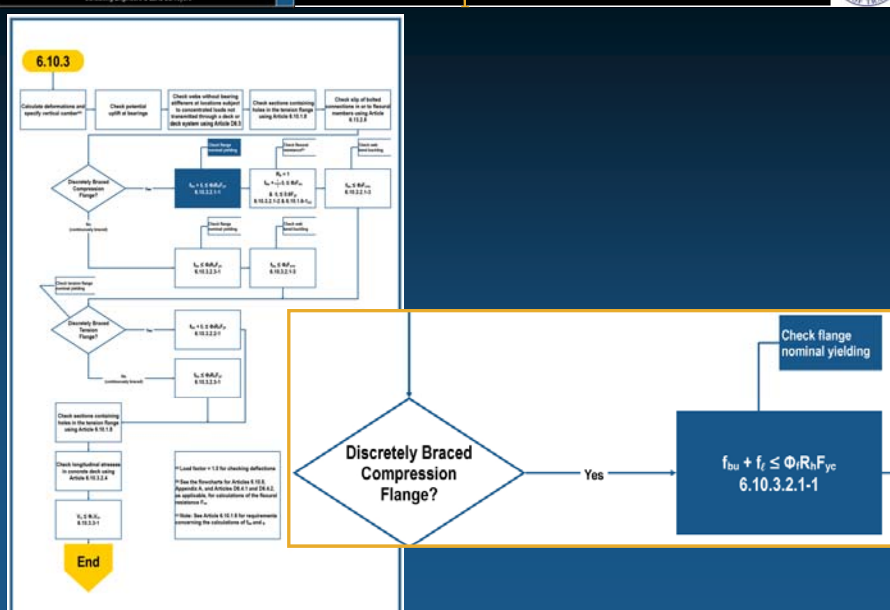

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Limit States

Yielding Limit State Check

This check ensures that the maximum combined stress in the compression flange will not exceed the specified minimum yield strength of the flange times the hybrid factor.

$$f_{bu} + f_{\ell} \leq \Phi_f R_h F_{yc}$$

6.10.3.2.1-1

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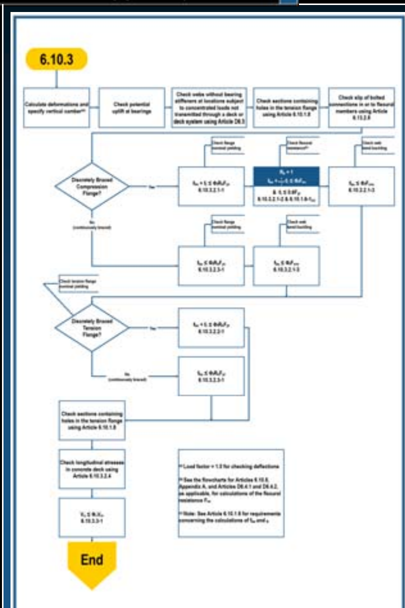

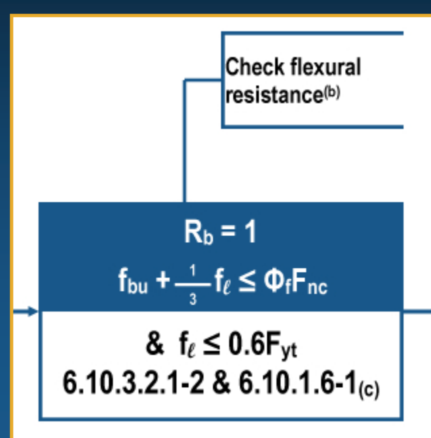

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Limit States

Lateral Torsional Buckling and Flange Local Buckling Check

This check ensures the member has sufficient strength with respect to lateral torsional and flange local buckling based limit states, including the consideration of flange lateral bending where these effects are judged to be significant.

$$R_b = 1$$

$$f_{bu} + \frac{1}{3} f_\ell \le \Phi_f F_{nc}$$

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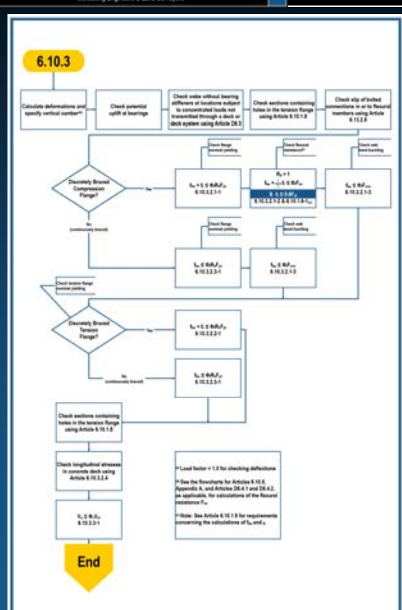
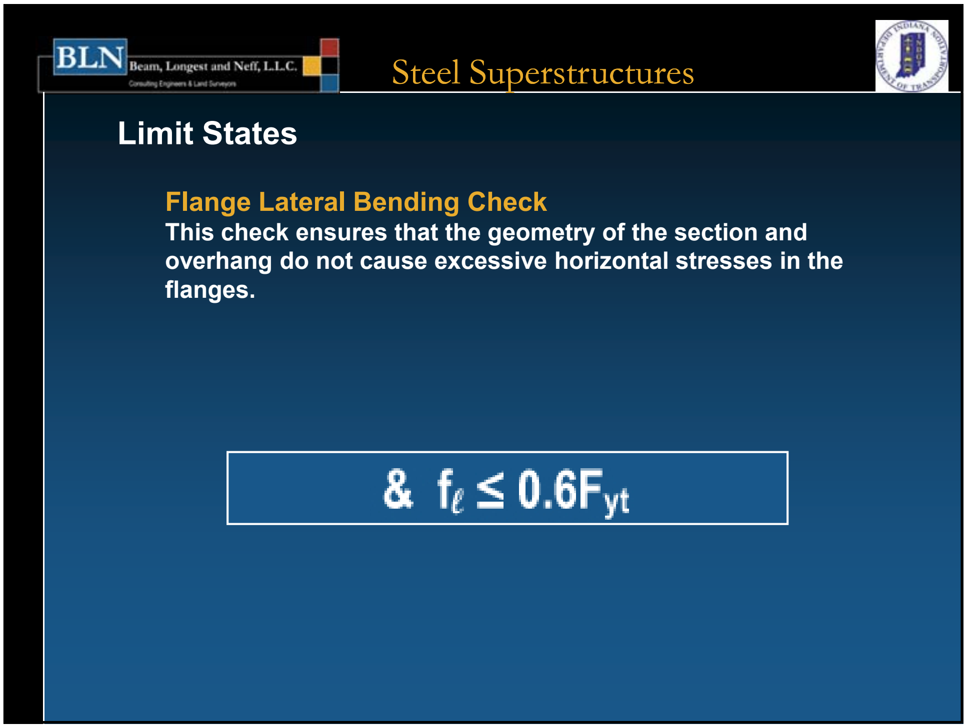


$$R_b = 1$$

$$f_{bu} + \frac{1}{3} f_\ell \le \Phi_f F_{nc}$$

$$\& \ f_\ell \le 0.6F_{yt}$$

6.10.3.2.1-2 & 6.10.1.6-1(c)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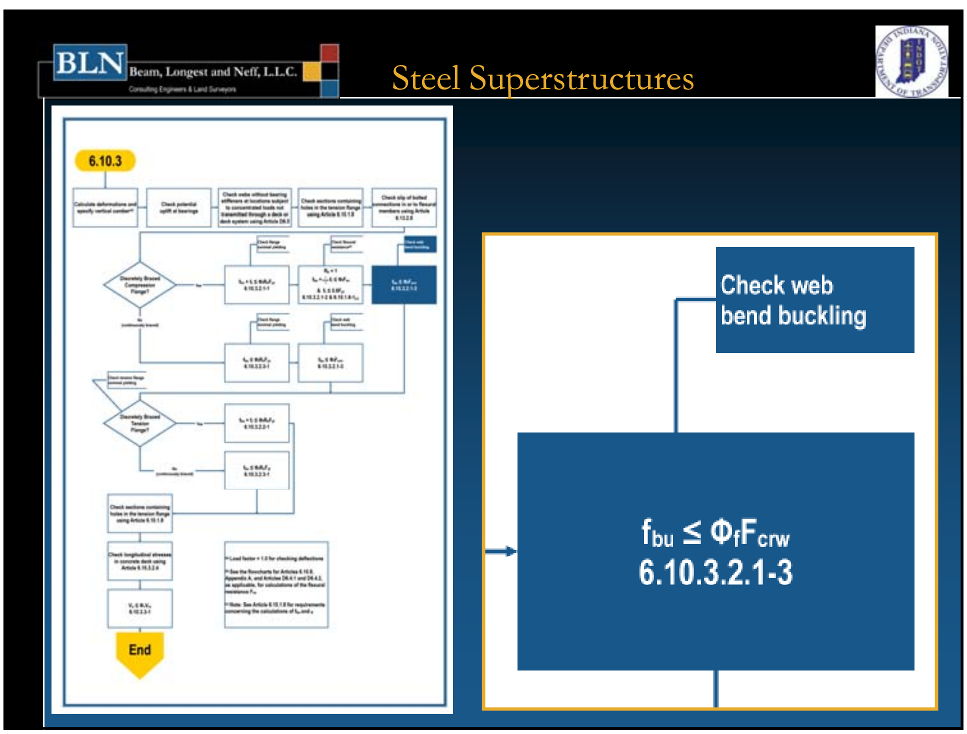
Limit States
Flange Lateral Bending Check
This check ensures that the geometry of the section and overhang do not cause excessive horizontal stresses in the flanges.
& $f_{\ell} \leq 0.6F_{yt}$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6.10.3
End
Check web bend buckling
$f_{bu} \leq \Phi_f F_{crw}$
6.10.3.2.1-3

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Limit States

Web Bend Buckling Check

This check ensures that the theoretical web bend-buckling will not occur in construction. This check need not be performed if the web is compact or non-compact per AASHTO 6.10.6.2.3.

$$f_{bu} \leq \Phi_f F_{crw}$$

6.10.3.2.1-3

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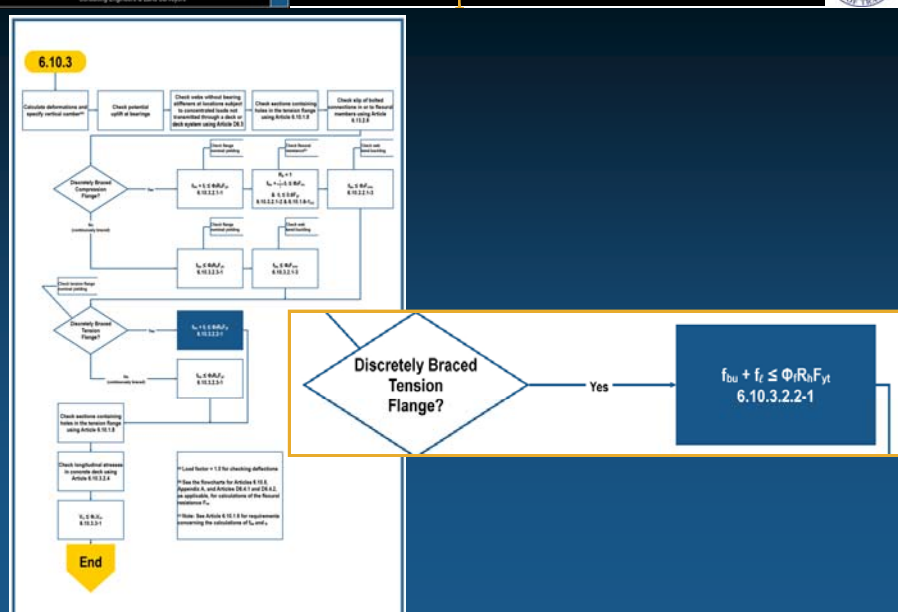

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Limit States

Discretely Braced Flange in Tension Check

This check ensures that the stress in the flange will not exceed the specified minimum strength of the flange times the hybrid factor during construction under the combination of the major-axis bending and lateral bending stresses due to factored loads.

$$f_{bu} + f_{\ell} \le \Phi_f R_h F_{yt}$$

6.10.3.2.2-1

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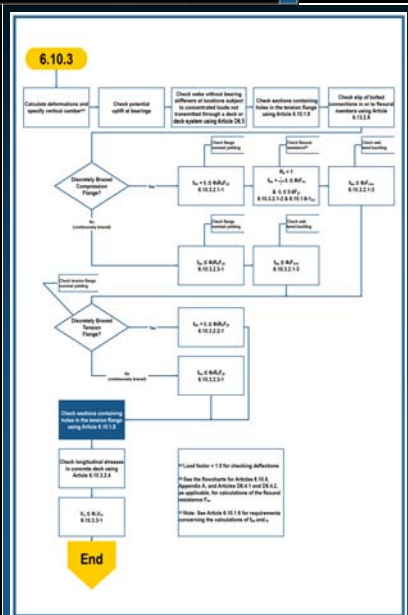

Check sections containing holes in the tension flange using Article 6.10.1.8

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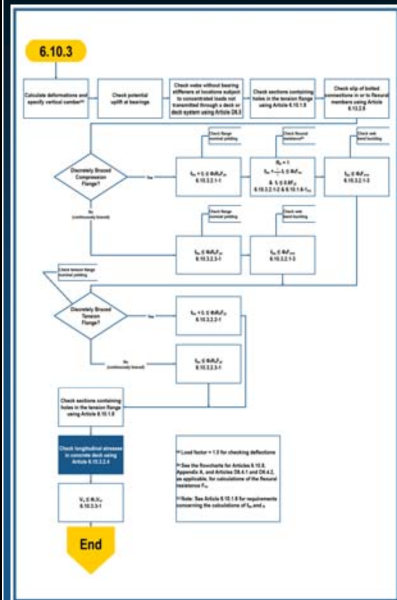

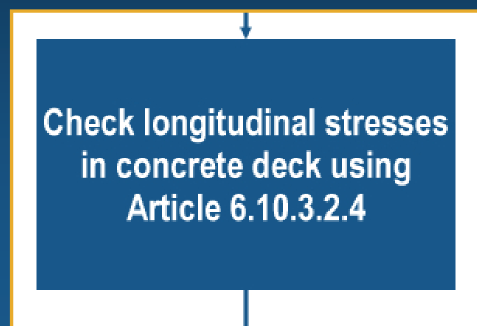

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AASHTO Steel Reference

6.10.1.7 Minimum Negative Flexure Concrete Deck Reinforcement

Wherever the longitudinal tensile stress in the concrete deck due to either the factored construction loads or Load Combination Service II in Table 3.4.1-1 exceeds φf_r , the total cross-sectional area of the longitudinal reinforcement shall not be less than one percent of the total cross-sectional area of the concrete deck. Φ shall be taken as 0.9 and f_r shall be taken as the modulus of rupture of the concrete determined as followed:

For normal-weight concrete: $f_r = 0.24$ sgrt(f'_c)

The longitudinal stresses in the concrete deck shall be determined as specified in Article 6.10.1.1.1d. The reinforcement used to satisfy this requirement shall have a specified minimum yield strength not less than 60.0 ksi and a size not exceeding No. 6 bars.


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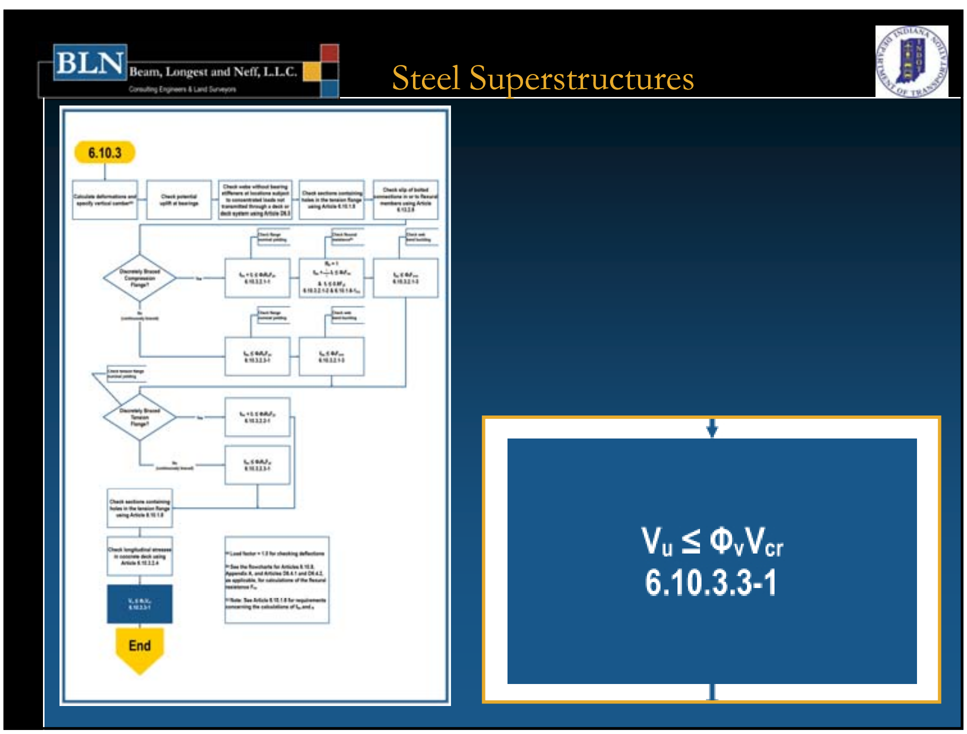
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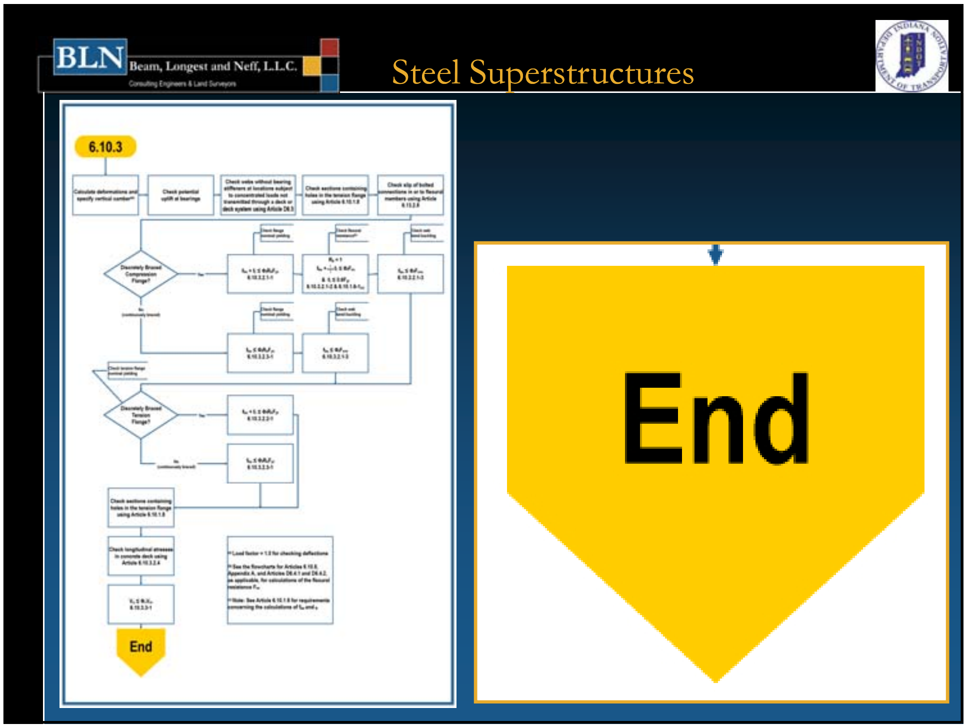
6.10.3
End
$V_u \leq \Phi_v V_{cr}$
6.10.3.3-1



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Steel Superstructures

Hybrid Plate Girders

Application:

HPS 70W steel in bottom flange of positive moment region

HPS 70W steel in top and bottom flanges of negative moment region

Costs:

HPS 70W often carries a cost premium of approximately 10% compared to Grade 50W.

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Hybrid Plate Girders

6.10.1.10 Flange-Strength Reduction Factors
6.10.1.10.1 Hybrid Factor, R_h

$R_h = 12 + B\,(3\rho - \rho^3) / (12 + 2\,\beta)$ (6.10.1.10.1-1)

$B = 2\,D_n t_w / A_{fn}$ (6.10.1.10.1-2)

C6.10.1.10.1

The R_h factor accounts for the reduced contribution of the web to the nominal flexural resistance at first yield in any flange element, due to the lower strength steel in the web of a hybrid section.

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Hybrid Plate Girders

References:

AASHTO Guide Specification for Highway Bridge Fabrication with HPS 70W

FHWA High Performance Steel Links Page

http://www.fhwa.dot.gov/bridge/hps.htm

FHWA High Performance Steel Designers' Guide

http://www.fhwa.dot.gov/bridge/guide03.htm


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ANY QUESTIONS?
AUG 28 2002
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