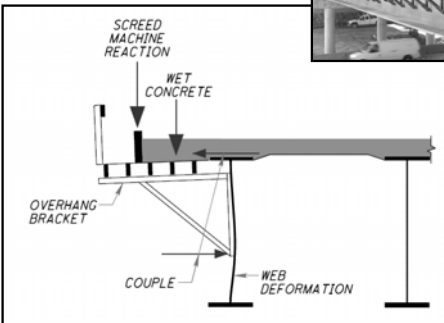
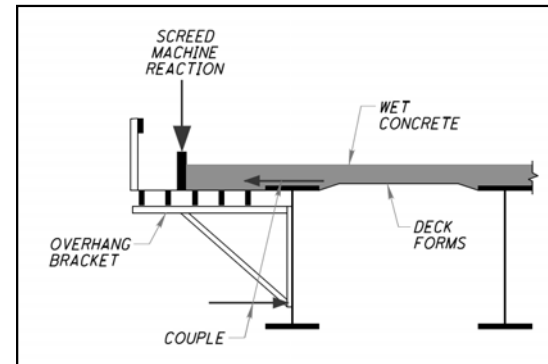


Deck Issues:
Design Perspective

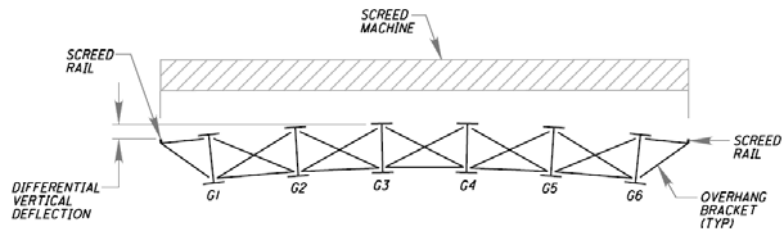


Overhang Bracket Loading



- Deck overhangs and screed rails are generally supported on cantilever brackets during the deck pour
- These brackets produce an overturning couple on the exterior girder

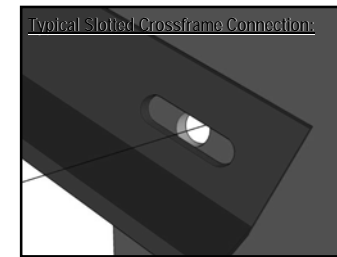
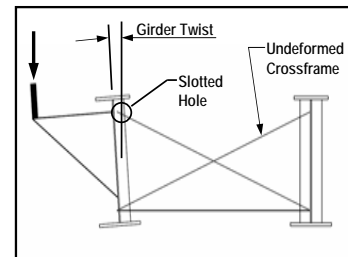
Screed Rail Deflection



- Girders and screed rails deflect as wet concrete load is added to the bridge.
- Twisting of the overhang bracket under wet concrete load results in differential deflection between the screed rail and the girders.
- This differential deflection can cause finished deck thicknesses to be incorrect.

Slotted Crossframe Connections:

- Slotted crossframe connections have been used commonly in the past to permit differential deflection between girders at crossframe locations.
- Slotted connections allow differential twisting to occur between girders and crossframes. This can cause a number of problems, including large screed rail deflections.
- The use of slotted crossframe connections is not recommended.



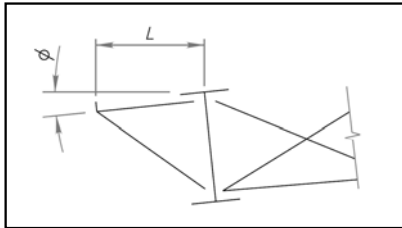
Overhang Bracket Twist

There are three primary components of twist in the overhang bracket:

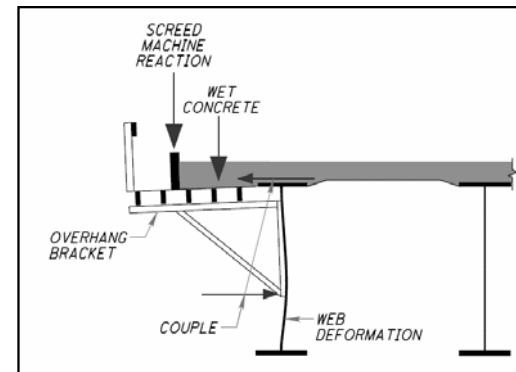
1. Twist due to "oil canning" effects, ϕ_o
2. Twist due to warping effects, ϕ_w
3. Twist due to global deflection, ϕ_g

Total twist ϕ is the sum of the three components:

$$\phi = \phi_o + \phi_w + \phi_g$$

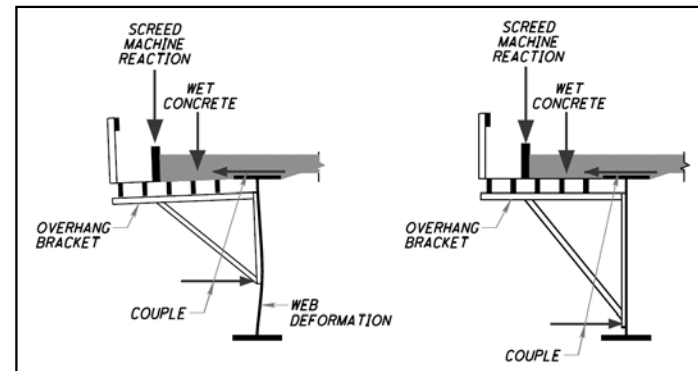
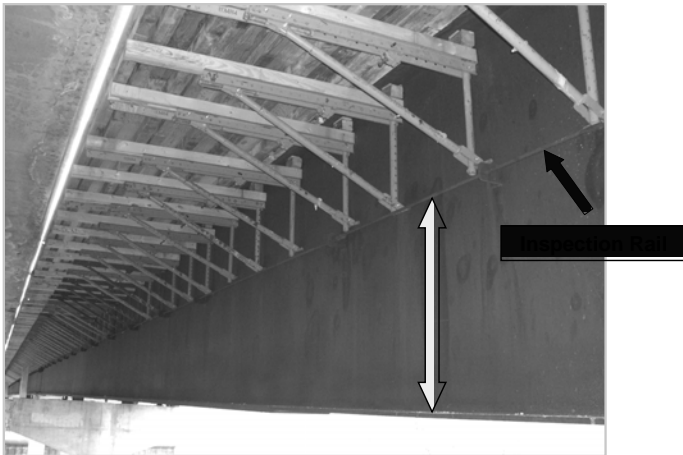


Component 1: Twist due to "oil canning" effects, ϕ_o



- Girder web deflection can occur due to lateral loads produced by the overhang bracket.
- We will refer to the effect as "Oil Canning".

Twist due to “oil canning” effects:



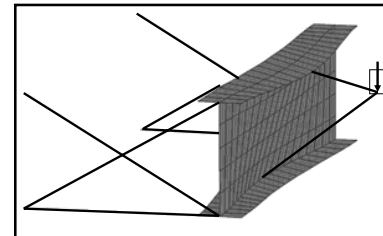
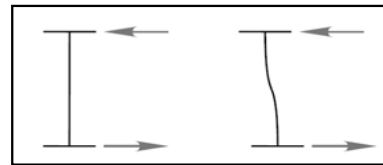
Prevention of oil canning effects:

- The diagonal leg of the overhang bracket should be placed as close to the bottom flange as possible.
- Adding transverse stiffeners increases the stiffness of the web.

Prediction of oil canning effects:

- For girders with web depths of less than 78 inches, oil canning effects can be neglected if the overhang bracket terminates within 8" of the bottom flange.
- The maximum depth of commonly available overhang brackets is 70 inches. So for web depths of greater than 78 inches, twist due to oil canning effects should be calculated by the designer.
- The magnitude of the twist can be predicted using finite element analysis of the web or by various approximate methods.

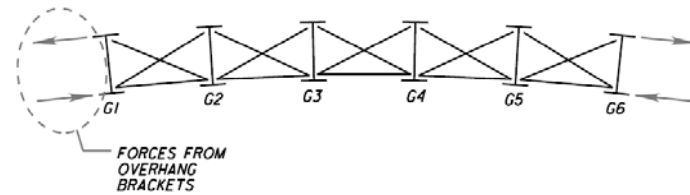
Component 2: Twist due to warping effects, ϕ_w



- Girder warping is cross-sectional distortion that occurs due to the application of a torsional load.
- Overhang loads produce twist between crossframes due to a combination of pure torsional deflection and girder warping.
- The girder is restrained against warping at the crossframe locations.

Twist due to warping effects:

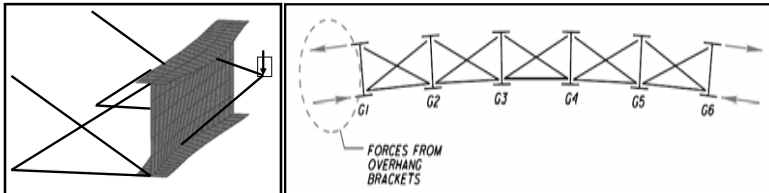
Cross
Frames



- The overhang couple also causes twisting to occur at crossframe locations due to crossframe deflections occurring across the width of the superstructure.
- ϕ_w is the total twist angle due to the combination of warping effects between crossframes and crossframe deflection across the structure width.

Prevention of warping effects

- Decreasing crossframe spacing reduces girder twist between crossframes and reduces the magnitude of the distortion occurring across the width of the structure.
- Warping between crossframes can be reduced by increasing the lateral stiffness of the girder flanges.
- Distortion across the width of the structure can be reduced by increasing the vertical stiffness of the girder sections.
- Weld or fully bolt crossframes during the deck pour.



Prediction of warping effects:

- Warping deformation can be predicted by finite element analysis of the exterior girder or by various approximate methods.
- TAEG (“Torsional Analysis of Exterior Girders”) software was developed by the Kansas Department of Transportation for the analysis of exterior girders under overhang bracket loads.
- TAEG uses an approximate method to calculate the effects of girder warping and deformation of the bridge cross section.
- TAEG does not address web deformation or twist due to differential girder deflections.
- TAEG can be downloaded from the Kansas DOT website.

TAEG 2.1

Torsional Analysis for Exterior Girders

Using TAEG:

- TAEG analysis is limited to only one crossframe type, an X-type brace with a top and bottom horizontal strut.
- Standard ODOT crossframes can be approximated using the “diaphragm” input.
- The formula below can be used to calculate the equivalent moment of inertia for an ODOT standard x-brace:

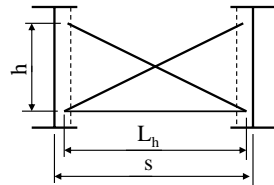
Moment of Inertia for Standard X-Brace (Approximate):

$$I = \frac{h^2 s}{4L_d^3 \left(\frac{1}{A_d L_h^2} + \frac{L_h}{A_h L_d^3 + A_d L_h^3} \right)}$$

A_d = Area of Diagonal Members

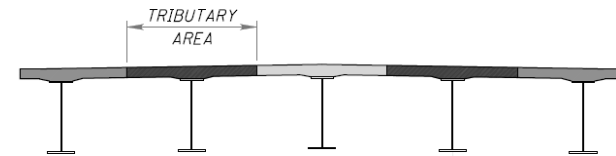
A_h = Area of Horizontal Member

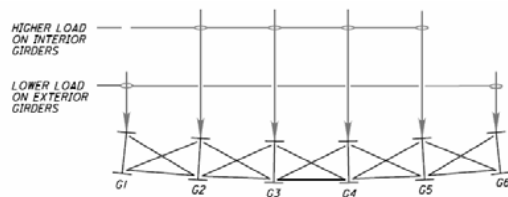
$$L_d = \sqrt{L_h^2 + h^2}$$



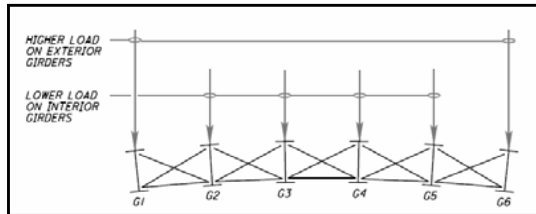
Component 3: Twist due to global deflection, ϕ_g

- Differential deflections may occur between adjacent girders during the deck pour due to different amounts of concrete dead load being applied to different girders.
- This most commonly occurs between interior and exterior girders due to large or small deck overhangs.

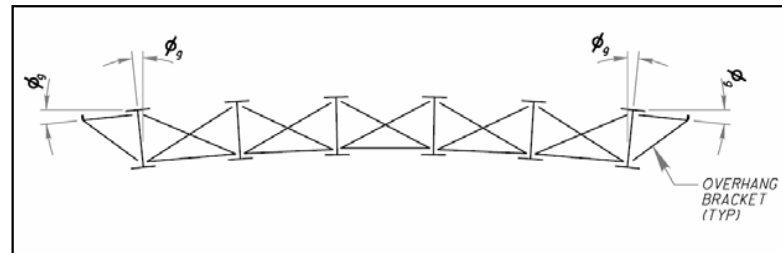




- Small overhangs result in lightly loaded exterior girders, and the cross section deflects in a concave shape. (“happy face” ☺)



- Large overhangs result in heavily loaded exterior girders, and the cross section deflects in a convex shape. (“frownie face” ☹)



- The twist occurring in the exterior girders due to global deflection causes an equivalent twist in the overhang bracket. The magnitude of this twist can be taken as ϕ_g .
- The value of ϕ_g will vary over the length of the bridge, and will be different for the left and right sides if loading or geometry is not symmetrical.

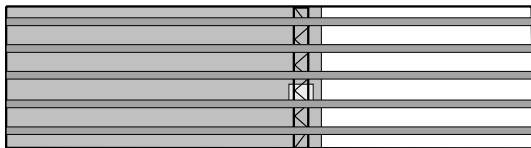
Prevention of twist due to global deformations:

- Avoid using large overhangs - Lightly loaded exterior girders result in concave (“happy face”) deflection, and a thick deck. Heavily loaded exterior girders result in convex (“frownie face”) deflection, and a thin deck.
- Weld or fully bolt crossframes during the deck pour – Loose or slotted crossframe connections do not restrain girders against twist.
- Add or stiffen crossframes - Higher crossframe stiffness results in more load distribution across the width of the structure and less distortion of the section.
- Increase vertical stiffness of girders – Stiffening the girders will reduce vertical deflection and decrease the overall magnitude of the cross-sectional distortion..

Prediction of twist due to global deformations:

- For conditions where the concrete deck load on the exterior girders is 110% or less of the deck load of the interior girders, global deformation can be ignored and ϕ_g can be taken as zero.
- If the concrete deck load on the exterior girders is greater than 110% of the deck load on the interior girders, a refined analysis of the structure should be performed. ϕ_g can be taken as the maximum exterior girder twist occurring due to the weight of the concrete deck.

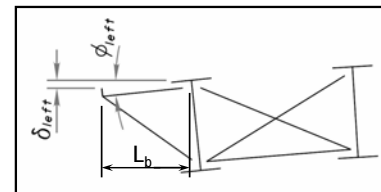
Effect of pour sequence on global deflection:



- When properly calculated, the global twist angle ϕ_g for a given location should be based on deflection occurring due to concrete present at the time that the screed machine passes over the point under consideration.
- This means that the loading to calculate ϕ_g for each point on the bridge will be different. A separate refined analysis would be needed for each point considered.
- It is generally conservative to calculate ϕ_g based on the full wet concrete load.
- On complex structures (variable skews, curved girders) the designer should consider a more detailed analysis of the pour sequence.

Calculation of Total Deck Thickness Loss:

The anticipated loss of deck thickness due to screed rail deflection can be calculated based on the total overhang bracket twist.



Step 1: Calculate overhang bracket twist for the left and right side.

$$\phi_{\text{left}} = (\phi_o + \phi_w + \phi_g)_{\text{left}}$$

$$\phi_{\text{right}} = (\phi_o + \phi_w + \phi_g)_{\text{right}}$$

Step 2: Calculate screed rail deflection for the left and right side.

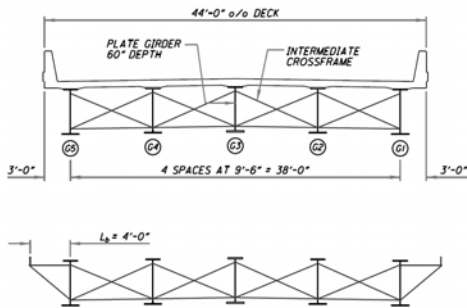
$$\delta_{\text{left}} = \tan(\phi_{\text{left}}) \times L_b$$

$$\delta_{\text{right}} = \tan(\phi_{\text{right}}) \times L_b$$

Step 3: Calculate loss of deck thickness.

$$\text{Loss} = (\delta_{\text{left}} + \delta_{\text{right}}) / 2$$

Sample Deck Thickness Loss Calculation:



Span = 150'-0"
Skew = 0°

Exterior Girder Concrete
Dead Load = .823 k/ft

Interior Girder Concrete
Dead Load = 1.01 k/ft

Left Side:

$\phi_o = 0^\circ$ (Girder Depth < 78")

$\phi_w = 0.3^\circ$ (From TAEG Analysis)

$\phi_g = 0^\circ$ (Exterior Concrete DL < 110% of Interior Concrete DL)

$\phi_{left} = (\phi_o + \phi_w + \phi_g)_{left} = (0^\circ + 0.3^\circ + 0^\circ) = 0.3^\circ$

Sample Deck Thickness Loss Calculation, Continued:

Right Side:

$\phi_o = 0^\circ$ (Girder Depth < 78")

$\phi_w = 0.3^\circ$ (From TAEG Analysis)

$\phi_g = 0^\circ$ (Exterior Concrete DL < 110% of Interior Concrete DL)

$\phi_{right} = (\phi_o + \phi_w + \phi_g)_{right} = (0^\circ + 0.3^\circ + 0^\circ) = 0.3^\circ$

Deck Thickness Loss:

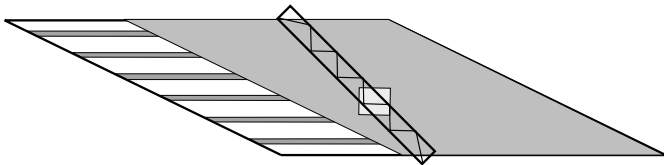
$\delta_{left} = \tan(\phi_{left}) \times L_b = \tan(0.3^\circ) \times 4.0 \text{ ft} \times 12 \text{ in/ft} = 0.25"$

$\delta_{right} = \tan(\phi_{right}) \times L_b = \tan(0.3^\circ) \times 4.0 \text{ ft} \times 12 \text{ in/ft} = 0.25"$

Loss = $(\delta_{left} + \delta_{right}) / 2 = (0.25" + 0.25") / 2 = \underline{0.25"}$

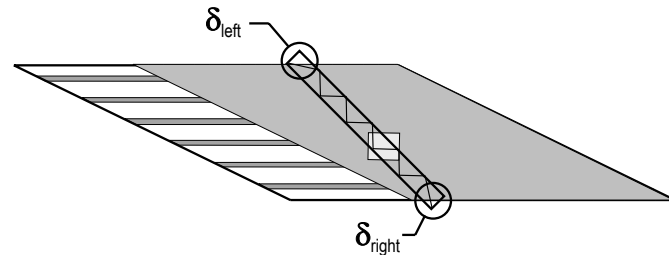
Deck thickness loss, Skewed Bridges:

- For bridges with supports constructed on a constant skew angle, deck thickness loss can be minimized by orienting the screed machine at the skew angle of the supports.
- The maximum skew for the screed machine is approximately 50° . For bridges with constant skews of greater than 50° , the screed machine should be oriented at a 50° skew.
- For bridges with variable skews, the designer must specify how the screed is to be oriented and calculated deck thickness loss based on this configuration.



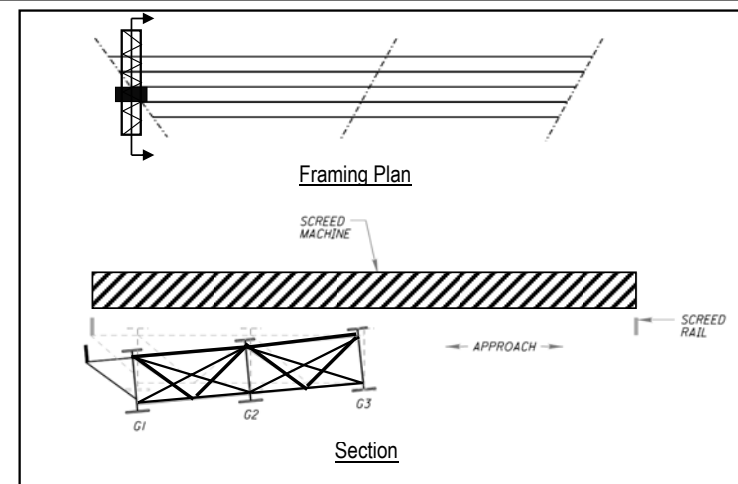
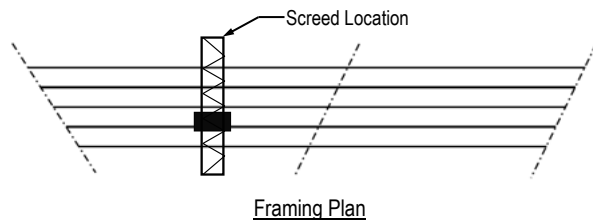
Deck Thickness Loss, Skewed Bridges, Continued:

- Screed rail deflection for skewed bridges can be calculated using the standard method presented earlier.
- When calculating the deck thickness loss, it is important to consider the orientation of the screed machine.
- δ_{left} and δ_{right} must be compared along the same angle as the screed machine, as illustrated below.

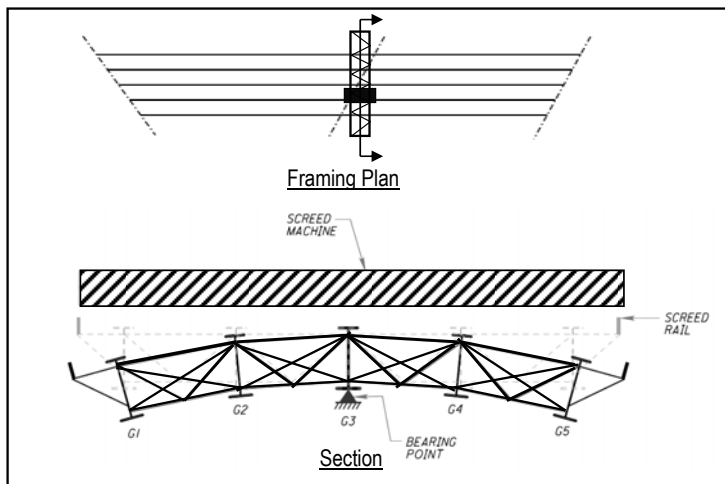


Variable Skews:

- On structures with substructures on variable skews, the designer should select the orientation of the screed machine before calculating deck thickness loss.
- Assumptions made regarding the orientation of the screed should be stated in the plans.
- Special attention should be given to deck thickness loss near the substructures when the screed is not oriented on the skew.

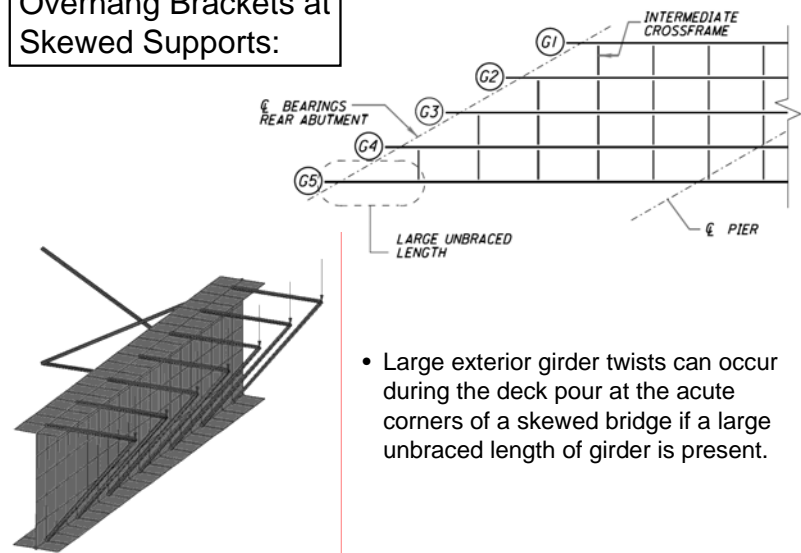


- Exterior girder twist can cause deck thickness loss when the screed machine straddles a skewed abutment.



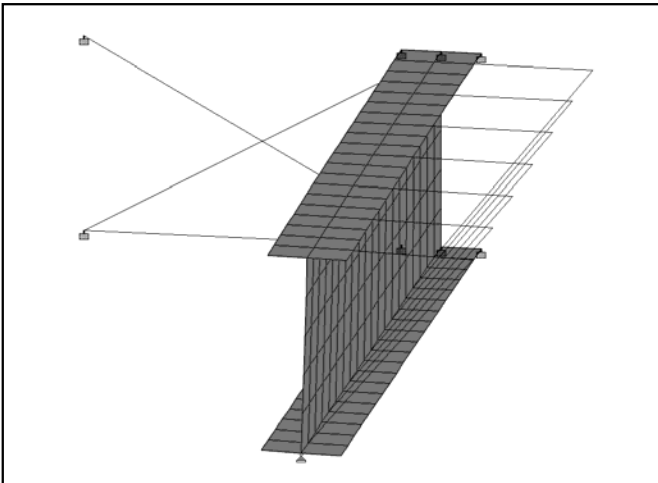
- Twist occurring in both exterior girders can cause deck thickness loss when the screed machine straddles a skewed pier.

Overhang Brackets at Skewed Supports:

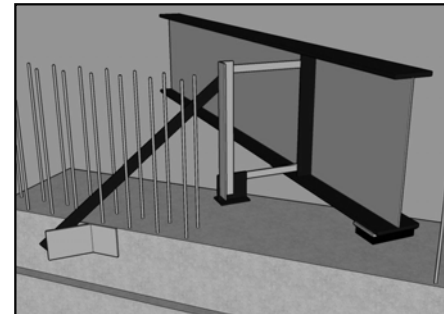
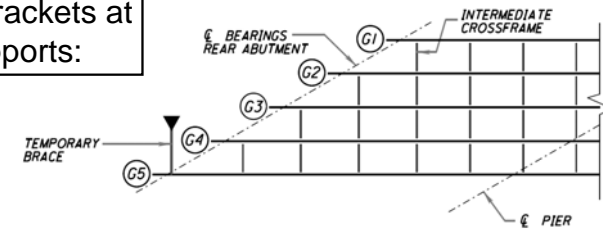


- Large exterior girder twists can occur during the deck pour at the acute corners of a skewed bridge if a large unbraced length of girder is present.

Overhang Brackets at Skewed Supports:



Overhang Brackets at Skewed Supports:

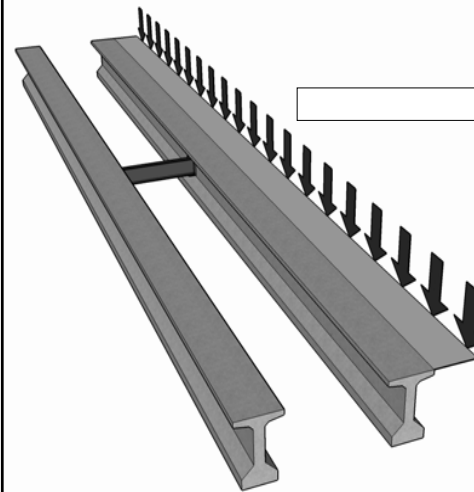


- A brace may need to be added near the bearing point in order to restrain the end of the girder and reduce deflections.

Torsional Effects in Prestressed I-Beam Bridges

- Prestressed concrete members generally have much more torsional stiffness than steel members.
- Girder twisting between crossframes can generally be neglected
- Because fewer intermediate crossframes are used in prestressed concrete structures, it is important to verify that the crossframes in the exterior bay are capable of carrying the torsion caused by the overhang load.

Torsional Effects in Prestressed I-Beam Bridges



- Standard Drawing PSID-1-99 requires only 1 diaphragm for spans 40 to 80 feet in length.
- Standard Drawing requirements are a minimum. The designer should add more diaphragms if required to carry the overturning moment due to the deck overhang.

QUESTIONS ?

E-mail questions to:

ose@dot.state.oh.us