Elite Training Series #2

Prestressed Concrete Composite Girder Bridge Design Check / Load rating / Excel Report Generation
What is Composite Girder Module?

- Wizard-modeling
  - Steel Composite Bridge
  - PSC Composite Bridge
- Changing the wizard information
- Making modifications

- Report Generation for design & load rating check
  - AASHTO
    - Steel Composite
    - PSC Composite
    - RC Pier
    - Cross-frames
  - Canada Code (To be implemented in August 2016)
    - Steel Composite
    - PSC Composite
Modeling Composite Structure

Line Girder model, analysis, design & rating check
Best modeling approach
  Manual modeling approach
    node/element functions
    table/text input

System model, analysis, design & rating check
Best modeling approach
  #1: Wizard
  #2: Manual / CAD Import
PSC Composite Wizard

Pre/Post-Tensioned Composite Girder Bridge Wizard

Layout | Section | Tendon | Load | Construction Stage

Centroid of deck

Deck width

Radius

Order Alignment

Boundary/Substructure

Without Substructure

Bearing Type/Elastic Link Stiffness

Abutment

Per

Material

Per Cap

Section

Length

Per Support

Open... | Save As.. | OK | Cancel

Elastic Link

Kx: 50 kips/ft

Ky: 10 kips/ft

Advanced...

PSC Composite Wizard
Design & Load Rating as per AASHTO

Chapter 1.
Prestressed Girder Design: AASHTO-LRFD

Strength Limit States
1. Flexural resistance
2. Shear resistance
3. Torsion resistance

Serviceability Limit States
1. Stress for cross section at a construction stage
2. Stress for cross section at service loads
3. Tensile stress for Prestressing tendons
4. Principal stress at a construction stage
5. Principal stress at service loads (Excluding torsional shear stress)
6. Principal stress at service loads
7. Check crack
Cracked Moment \((M_{cr})\)

For composite sections, the equation 1.16 is used to calculate the cracked moment \((M_{cr})\).

\[
M_{cr} = \gamma_3 \left[ (\gamma_1 f_r + \gamma_2 f_{cpe}) S_c - M_{dnc} \left( \frac{S_c}{S_{nc}} - 1 \right) \right]
\]  

(1.16)

\(M_{dnc}\) = total unfactored dead load moment acting on the monolithic or noncomposite section (kip-in.)

\(S_c\) = section modulus for the extreme fiber of the composite section where tensile stress is caused by externally applied loads (in.\(^3\))

\(S_{nc}\) = section modulus for the extreme fiber of the monolithic or noncomposite section where tensile stress is caused by externally applied loads (in.\(^3\))

The \(M_{dnc}\) is taken from the Muy caused by the dead load of girder section during the construction stage analysis.

The \(S_{nc}\) value is obtained from the section modulus of the pre-composite section under the tensile stress. The \(S_c\) value is taken from the section modulus of the post-composite section under the tensile stress.

In midas Civil, cracked moment shall be calculated as per the following equation.

(For the composite type sections, the equation 1.16 is used; for the non-composite type sections, the equation 1.17 is used.)

\[
M_{cr} = \gamma_3 \left[ (\gamma_1 f_r + \gamma_2 f_{cpe}) S_c \right]
\]  

(1.17)
2.8 Interface Shear

For the composite sections, the Shear Friction caused during construction sequences needs to be considered. Therefore, the Interface Shear check function is activated for the pre-composite section design check.

2.8.1 Calculate Vni

\[ V_{ni} = cA_{cv} + \mu (A_{cf}f_y + P_c) \]  \hspace{1cm} (5.8.4.1-3)

The nominal shear resistance, \( V_{ni} \), used in the design shall not be greater than the lesser of:

\[ V_{ni} \leq K_1 f_a A_{cv} \text{, or} \]  \hspace{1cm} (5.8.4.1-4)

\[ V_{ni} \leq K_2 A_{cv} \]  \hspace{1cm} (5.8.4.1-5)

in which:

\[ A_{cv} = b_{ci} L_{vi} \]  \hspace{1cm} (5.8.4.1-6)

The \( V_{ni} \) value is calculated based on the above calculation. The \( A_{cv} \) is the Interfacial Shear section area. The \( A_{cf} \) value is the cross section of the shear reinforcement of the Interfacial Shear section. The following equation (5.8.4.4-1) needs to be satisfied about the minimum shear reinforcement rea.

\[ A_{yf} \geq \frac{0.05A_{cv}}{f_y} \]  \hspace{1cm} (5.8.4.4-1)
The \( P_c \) value is the compressive force acting on the interface. In the program, the \( P_c \) value is calculated based on the selfweight of slab.

The program suggests the factors used in design. In midas Civil, they are applied as shown below:

**Table. The design factors used in midas Civil**

5.8.4.3—Cohesion and Friction Factors

The following values shall be taken for cohesion, \( c \), and friction factor, \( \mu \):

- For a cast-in-place concrete slab on clean concrete girder surfaces, free of laitance with surface roughened to an amplitude of 0.25 in.
  
  \[
  \begin{align*}
  c &= 0.28 \text{ ksi} \\
  \mu &= 1.0 \\
  K_1 &= 0.3 \\
  K_2 &= 1.8 \text{ ksi for normal-weight concrete} \\
        &= 1.3 \text{ ksi for lightweight concrete}
  \end{align*}
  \]

- For normal-weight concrete placed monolithically:
  
  \[
  \begin{align*}
  c &= 0.40 \text{ ksi} \\
  \mu &= 1.4 \\
  K_1 &= 0.25 \\
  K_2 &= 1.5 \text{ ksi}
  \end{align*}
  \]

AASHTO-LRFD12 Standard
In \( Acv = bci \times Lvi \), bci value is taken from the Bvi input by the user and the Lvi value is taken from the girder length of the program model.

The \( Avf \) is the cross section of the reinforcement rebars in the interfacial shear plane (\( Acv \)). The calculator is activated when the button is clicked. So that the cross section is calculated based on the rebar diameter, number and gap inputted by the user.

\[
V_{ri} = \phi V_{nl} \quad (5.8.4.1-1)
\]

and the design shall satisfy:

\[
V_{ri} \geq V_{ui} \quad (5.8.4.1-2)
\]

The \( V_{ri} \) value is calculated based on the above equation (5.8.4.1-1). Also, the \( V_{ri} \) value should be equal to or greater than \( V_{ui} \).

For PSC design check, the \( \Phi \) is taken as 1.0.

The Interface Shear calculation can be reviewed in the MS Excel Report.

The Interface Shear check result can be also checked in the Shear Resistance Results table.
3. Torsion resistance

Check the combined shear and torsional resistance.

3.1 Dimension of section for torsion

The dimensions of section that are required for checking torsion are as follows:

- $A_o$: Area enclosed by the shear flow path, including any area of holes therein (in²)
- $Ph$: Perimeter of the centerline of the closed transverse torsion reinforcement (in)
- $Ac_p$: Total area enclosed by outside Perimeter of the concrete section (in²)
- $P$: The length of the outside perimeter of concrete section (in)

Fig. 1.24 Dimension of section for torsion
**Additional information for the torsional area Ac and circumference Ph calculation of the composite section.

In midas Civil, when Ao section is applied for the composite section, the girder and slab sections (section areas with the Torsion Thk Offset applied in the Section Manager) are calculated separately and then added. The Ph circumference is calculated based on the same approach but the value of bw*2 is subtracted in order to consider the contact area between the girder and slab.

ex)

![Diagram]

bw
PSC Composite Design check

- **Material selection**
  - Separate material definition girder and slab
  - Light concrete factor

- **Interface shear consideration**
  - Surface classification by 5.8.4.3
  - Interface width & reinforcement area
  - Shear connector definition
Design result table

- **Strength**
  - Flexure
  - Shear
  - Combined shear and Torsion

- **Stress**
  - Sectional & Principal stress
    - Per construction stage
    - Under service load case
  - Tendon tensile stress

- Crack width under service load

<table>
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<tr>
<th>Elem</th>
<th>Part</th>
<th>Positive/ Negative</th>
<th>LCom Name</th>
<th>Type</th>
<th>CHK</th>
<th>Muy (ft/kips)</th>
<th>Mcr (ft/kips)</th>
<th>Mny (ft/kips)</th>
<th>PhiMny (ft/kips)</th>
<th>Ratio (Muy/PhiMny)</th>
<th>PhiMny/min(1.5Muy/Mcr)</th>
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</table>
Design result Report

2) Checking Torsional Effects

- Torsional cracking moment ($T_{cr}$):
  \[ b_e = 11.000 \text{ (ksi)} \]
  The effective thickness of shear flow path of elements
  \[ T_{cr} = 0.0632K_v f_c2A_0b_e = 6809.30 \text{ (kips-in.)} \]
  \[ (Eq. 5.8.6.3-2) \]
  \[ T_u = 1304.30 \text{ (kips-in.)} \leq (1/3)T_{cr} = 2289.77 \text{ (kips-in.)} \]
  \[ (Eq. 5.8.6.3-1) \]
  \[ T_u \leq (1/3)T_{cr}, \text{ Ignore Torsional Effects.} \]

- Check torsional moment
  \[ T_u = 1304.30 \text{ (kips-in.)} > \Phi T_n = \frac{\Phi 2 A_0 A_1 f_y}{s_t} = 0.00 \text{ (kips-in.)} \]
  \[ (Eq. 5.8.6.4-2) \]

- Required longitudinal reinforcement
  In box section,
  \[ A_1 = 0.00 \text{ (in.}^2) \leq (T_u/\Phi)p_0/(2A_0 f_y) = 1.73 \text{ (in.}^2) \]
  \[ (Eq. 5.8.3.6.3-2) \]
  \[ \text{NG} \]

- Check combined torsional and shear
  \[ \frac{V_u}{b_d v} + \frac{T_u}{2A_0b_e} = 0.14 \text{ (ksi.)} < 0.474 f_c = 1.01 \text{ (ksi.)} \]
  \[ (Eq. 5.8.6.5-5) \]
  \[ \text{OK} \]
PSC Composite Load rating

- Rating parameters
  - Limit state stress for Service / Fatigue / Pre-stress

- Material selection

- Rating group
  - Structure Group compatible

- Rating case definition
  - User friendly
  - Primary / Adjacent vehicle
Rating result table

- Summary table
  - Limit state stress for
  - Service limit state
  - Strength limit state

- Rating factor
  - Concrete stress
  - Pre-stressing Tension
  - Flexural & shear strength
  - Strength limit state

- Rating factor detailed table

<table>
<thead>
<tr>
<th>Group</th>
<th>Elem.</th>
<th>Part</th>
<th>Girder/Slab</th>
<th>Relative Location</th>
<th>Comp./Tens.</th>
<th>Rating Case</th>
<th>Rating Factor</th>
<th>Check</th>
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<td>Girder(Composite)</td>
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# Load rating report

## AASHTO Load Rating Summary Result Table

### Load Rating Summary Detail for Prestressed Concrete Girder Bridge (Strength Limit)

<table>
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<tr>
<th>Level</th>
<th>Load Combination</th>
<th>Moving Load Case</th>
<th>Weight (tons)</th>
<th>Load Factors</th>
<th>Moment (Strength, kip in)</th>
<th>Shear (kips)</th>
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<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>DC</td>
<td>DW</td>
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<tr>
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<td>min</td>
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**Where:**
- **Level Type**
  - DL: Design Load Rating
  - LL: Legal Load Rating
  - PL: Permit Load Rating
- **Load Factor Description**
  - LL: Load Factor of primary vehicle load case
  - DC: Load Factor of dead load case
  - DW: Load Factor of dead load case of wearing surfaces and utilities

### Load Rating Summary Detail for Prestressed Concrete Girder Bridge (Service Limit)

<table>
<thead>
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<th>Load Factors</th>
<th>Stress Girdr (Service, kip/in²)</th>
<th>Stress Slab (Service, kip/in²)</th>
<th>Composite Section</th>
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<td></td>
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<td>DW</td>
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<td>1.00</td>
<td>1.00</td>
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</tr>
</tbody>
</table>

**Where:**
- **Level Type**
  - DL: Design Load Rating
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