One Stop Solution
for Bridge and Civil Structures

midas Civil

Advanced Application 14

Prestressed Box Girder Design

(AASHTO LRFD 2012)

Program Version	Civil 2013
Program License	Registered
Revision Date	Aug 17, 2012

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Overview

Design procedure for PSC section is as follows.

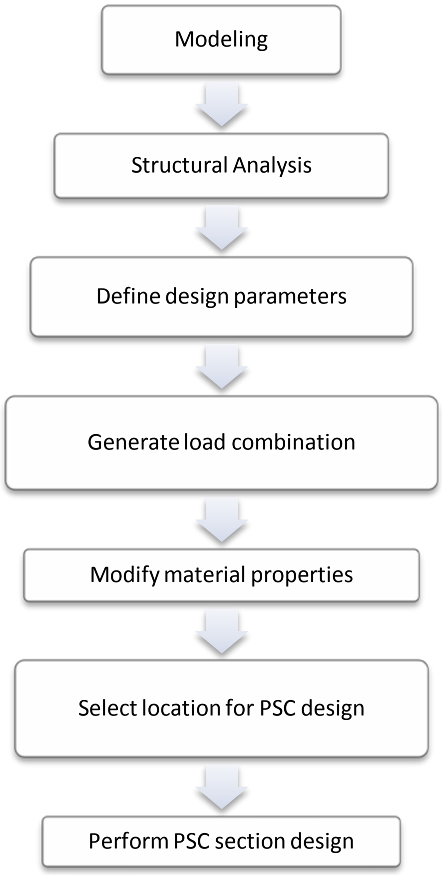


Fig.1 Procedure for PSC section design

There are some limitations of PSC design function in midas Civil.

1. Construction stage analysis should be performed because PSC section needs to be checked during the construction stage and the service state.

2. PSC section design can be performed for the beam elements only. All the elements which are on the X-Y plane are taken as Beam members and those with some inclination to X-Y plane are designated as Column members by midas Civil. However, these automatically assigned member types to elements can be modified using ***Modify Member Type*** function (Path: *Design> Common Parameters> Modify member Type*).

In this tutorial, we first open FSM bridge and add reinforcement. Then we will perform PSC section design for the construction stage and the service state.

Bridge specification and Cross-Section

Bridge type: 3-span continuous PSC Box Bridge (FSM)
Bridge length: L = 40.0+ 45.0 + 40.0 = 125.0 m
Bridge width: B = 8.5 m (2 lanes)
Skew : 0˚(No skew)

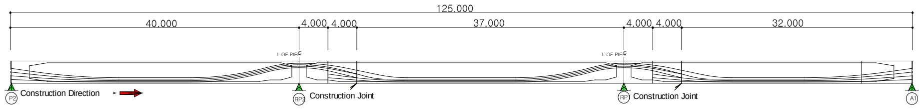


Fig. 2 Longitudinal section view Unit: m

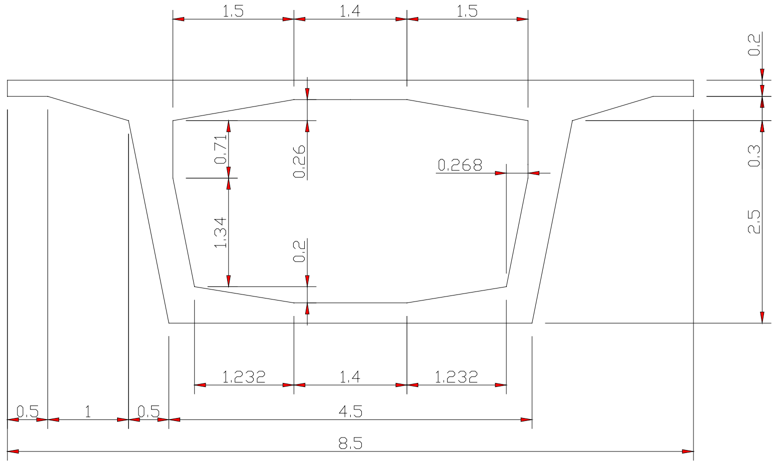
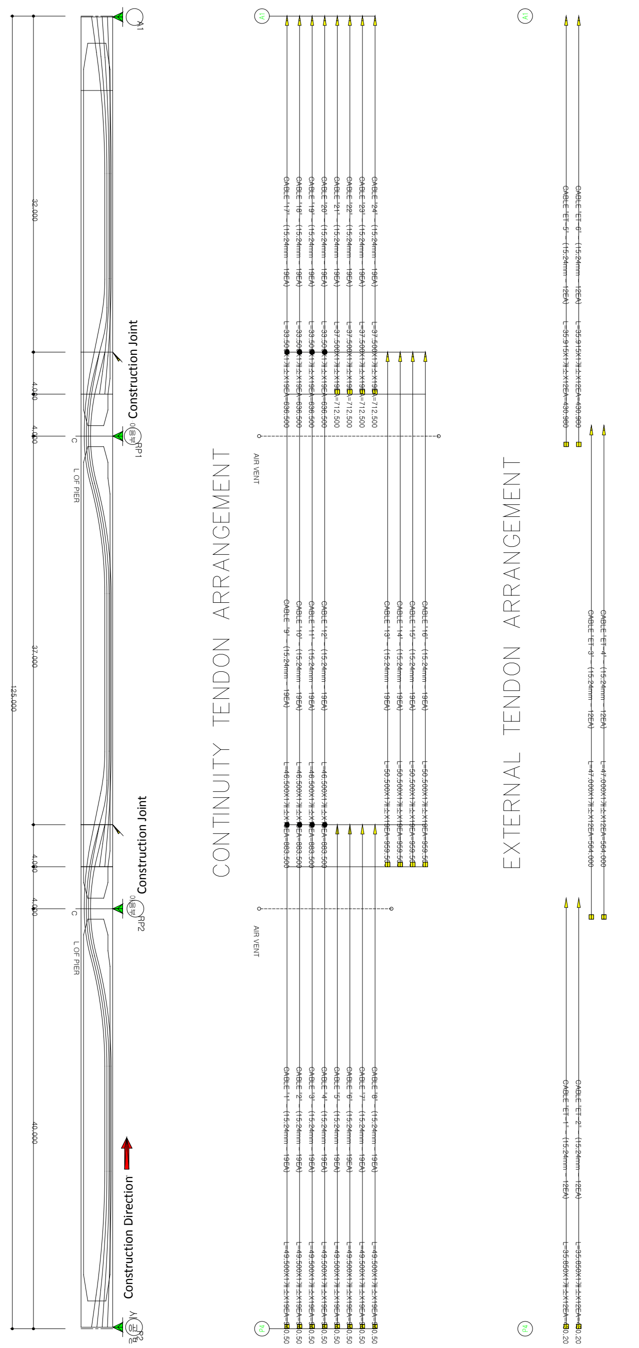


Fig. 3 Typical cross section Unit: m



Unit: m

Fig.4 Tendon Profile

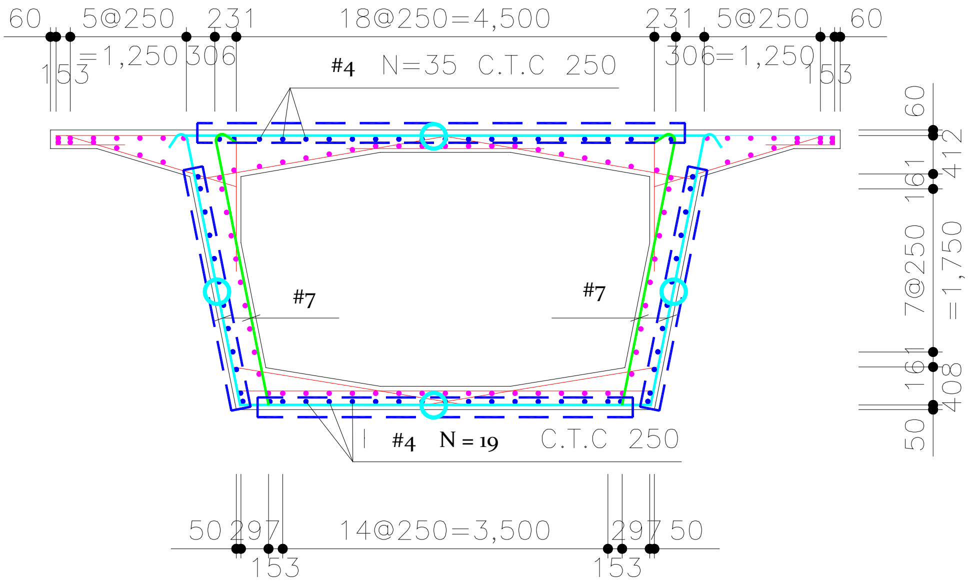


Fig.5 Reinforcement Unit: mm

Material Properties and Allowable Stress

- **Concrete properties for superstructure**
  ASTM Grade: C5000

- **Tendon Properties**
  P.C Strand: Φ15.2 mm (0.6″strand)
  Yield Strength: f_{py} = 1600 N/mm^2
  Ultimate Strength: f_{pu} = 1900 N/mm^2
  Cross Sectional area: A_p = 2635.3 mm^2
  Modulus of Elasticity: E_{ps} = 2.0 X 10^5 N/mm^2
  Jacking Stress: $f_{pj} = 0.7 f_{pu}$ = 1330 N/mm^2
  Curvature friction factor: μ = 0.3 /rad
  Wobble friction factor: k = 0.0066 /m
  Anchorage Slip: Δs = 6 mm (At the Beginning and at the End)

Check cross section dimensions of the girder
(AASHTO-LRFD 5.14.2.3.10)

- **Check the thickness of flanges**
  - Top flanges:
    Clear span between webs, lw = 4400 mm
    Minimum thickness = 4400/30 =146.667 mm
    Top flange thickness = 240 mm. OK.
  - Bottom flanges:
    Clear span between webs, lw = 3864 mm
    Minimum thickness = 3864/30 =128.8 mm
    Bottom flange thickness = 250 mm. OK.

- **Check whether transverse prestressing is required or not**
  lw = 4.400 m < 4.57 m(= 15 feet) Transverse prestressing not required.

- **Check web thickness**
  Minimum thickness, t_{min} = 304 mm (= 12 inches)
  Web thickness, tw = 318 mm. OK.

- **Check the length of top flange cantilever**
  The distance between centerline of the webs: l_n = 4950 mm
  l_n X 0.45 = 2228 mm > 1500 mm. OK.

- **Check overall cross-section dimensions**
  Maximum live load plus impact deflection: 6.433 mm
  Deflection limit, L/1000 = 45000/1000 = 45 mm. OK.

Load

- **Dead Load**

  Self weight

  Input Self-Weight

  Superimposed dead load

  w = 35.796 kN/m

- **Prestress**

  Strand (ϕ15.2 mm×19 (ϕ0.6″- 19))

  Area: A_p = 2635.3 mm^2

  Duct Size: 103 mm

  Prestressing force: 70 % of ultimate strength. $f_{pj} = 0.7 f_{pu} = 1330\ N/mm^2$

  Prestressing losses after the initial loss (automatically calculated by program)

  Friction Loss: $P_{(X)} = P_0 \cdot e^{-(\mu\alpha + kL)}$

  μ = 0.3 /rad, k = 0.006 /m

  Anchorage Slip Loss: ΔI_c = 6 mm

  Elastic Shortening Loss: $\Delta P_E = \Delta f_P . A_{SP}$

  Final Loss (automatically calculated by program)

  Relaxation (CEB-FIP)

  Creep and Shrinkage Loss (CEB-FIP)

- **Creep and Shrinkage**

  Code: CEB-FIP (1990).

  Characteristic compressive strength of concrete at the age of 28 days : 34.474 N/mm^2.

  Relative Humidity of ambient environment: 70%

  Notational size of member: 364 mm.

  Type of cement: Normal or rapid hardening cement (N, R).

  Concrete age when subjected to long term loads: t_0 = 5 days

  Age of concrete at the beginning of shrinkage: 3 days

  Air temperature or curing temperature: T = 20˚C

  Creep Coefficient: Automatically calculated within the program

  Shrinkage Coefficient: Automatically calculated within the program

- **Live loads**

  Condition

  A. Vehicle Load : HL-93TDM, HL-93TRK
  B. Dynamic Allowance : 33%

- **Support Settlement**

  Consider each pier undergoing the support settlement of 10 mm under unfavorable condition.

- **Temperature Loads**

  Temperature Range for Procedure A (assuming Moderate climate)

  10 degree to 80 degree F

  Temperature Gradient (assuming Zone 2)

  -Positive temperature value

  T1 = 46˚F

  T2 = 12˚F

  -Negative temperature value

  T1 = -0.3 X 46˚F = -13.8˚F

  T2 = -0.3 X 12˚F = -3.6˚F

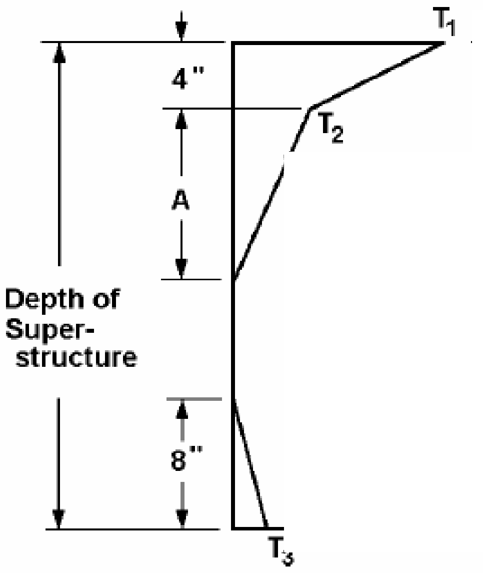


Fig. 6 Positive Vertical Temperature Gradient

- **Wind Loads**

Wind Load: 3 kN/m^2

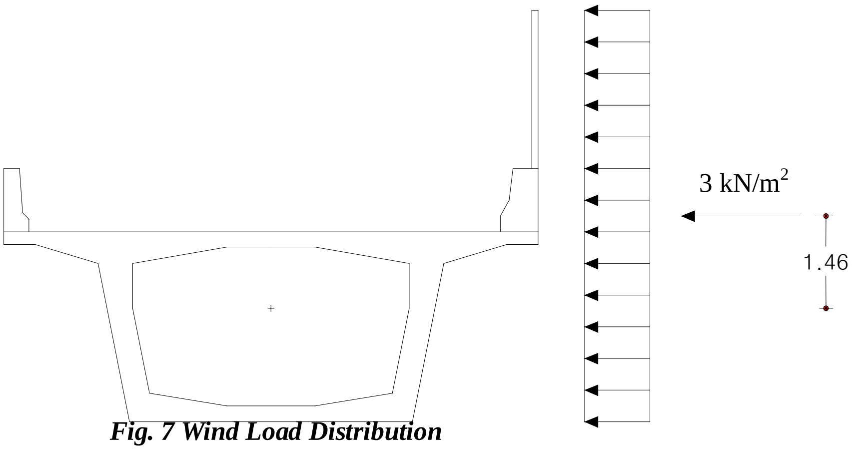


Fig. 7 Wind Load Distribution

Total Height = Section Depth + Barrier + Noise barriers = 3+1+2.5 = 6.5 m
Wind Pressure = 3 kN/m^2
Wind Load = 6.5 X 3 kN/m^2 = 19.5 kN/m (Horizontal Load)
= 19.5 kN/m X -1.46m = -28.47 kN.m/m (Moment)

Open model file and Save

For construction stage analysis of FSM bridge, open (***Open Project***) 'FSM' file, and then save the file as **'PSC Design'**

/ ***Open Project***
/ ***Save As…(*****PSC Design*****)***

Check the model data

In this tutorial, the effects of reinforcement has been considered for the calculation of the section property and creep restraint.

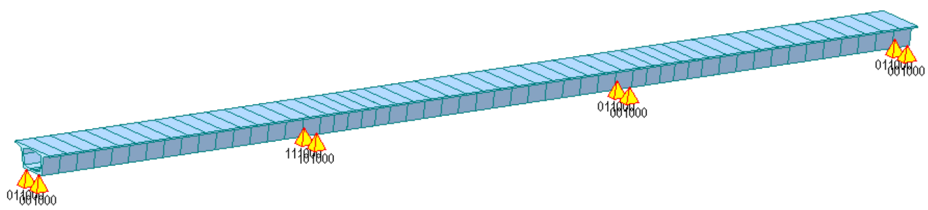


Fig. 8 FSM model used for section check

Reinforcement Input

Enter longitudinal reinforcement, shear reinforcement and torsion reinforcement data of the PSC section. The reinforcement data of the PSC box is as follows.

In this tutorial, the arrangement of longitudinal rebars has been simplified for convenience.

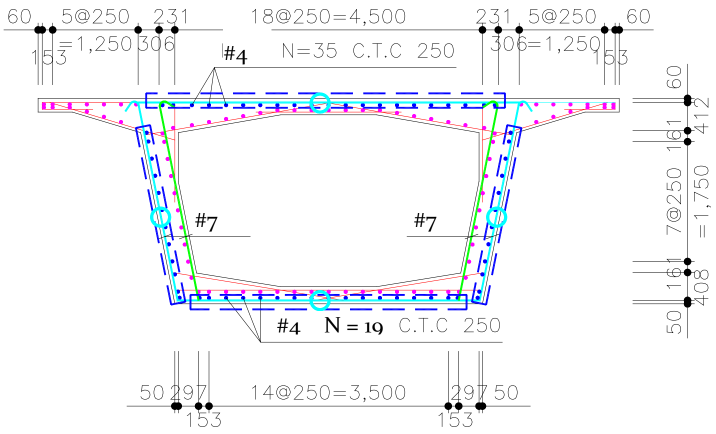


Fig. 9 Reinforcement in longitudinal direction Unit: mm

The shear/torsion reinforcement data of the PSC box is as follows.

Table 1. Shear/torsion reinforcement data

Shear reinforcement	Pitch	0.15 m
	Angle	90°
	Alt	0.0015484 m^2 (4-#7)
Torsion reinforcement	Pitch	0.15 m
	Awt	0.0003871m^2 (1-#7)
	Alt	0.0078554m^2 (62-#4)

Let's assume that the longitudinal reinforcement, shear reinforcement, and torsion reinforcement are same throughout the bridge.

We can enter the longitudinal reinforcement and shear reinforcement data by selecting all the elements at a time, because there is same reinforcement throughout the bridge.

Aw is the area of vertical re-bars which are placed in the web and Awt is the area of one leg of outermost closed stirrups (Fig. 9) of the closed stirrups placed towards the exterior.

Alt is the total area (Fig 9.) of longitudinal torsion reinforcement distributed around the perimeter of the closed stirrups.

Properties / Section Manager / ***Reinforcement of Section***

Section List> 1:**Span**

Longitudinal reinforcement

1. Dia (**#4**), Number (**35**), Ref. Y (**Centroid**), Y (**0**), Ref. Z (**Top**), Z (**0.06**), Spacing (**0.25**).
2. Dia (**#4**), Number (**19**), Ref. Y (**Centroid**), Y (**0**), Ref. Z (**Bottom**), Z (**0.06**), Spacing (**0.25**)

Shear Reinforcement

Diagonal Reinforcement>Pitch **(0.15)**, Angle **(90)**, Aw **(0.0015484)**

Torsion Reinforcement >Pitch **(0.15)**, Awt **(0.0003871)**, Alt **(0.0078554)** ↵

By checking on "Same Rebar Data at (i & j) end", the reinforcement data of one part will be copied to another.

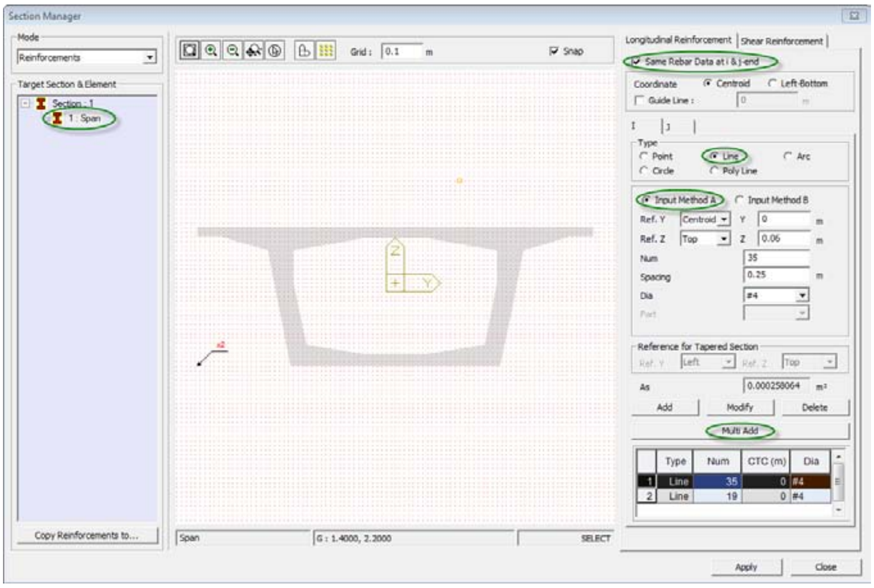


Fig. 10.1 Longitudinal Reinforcement of PSC section

Reinforcement Multi Add

Type: Line (Input Method A)

	Type	Input Method	Ref.Y	Ref.Z	Y	Z	Num	Spacing	Dia	Part	Ref.Y	Ref.Z
1	Line	Method A	Centroid	Top	0	0.06	35	0.25	#4		Left	Top
2	Line	Method A	Centroid	Bottom	0	0.05	19	0.25	#4		Left	Top
3												

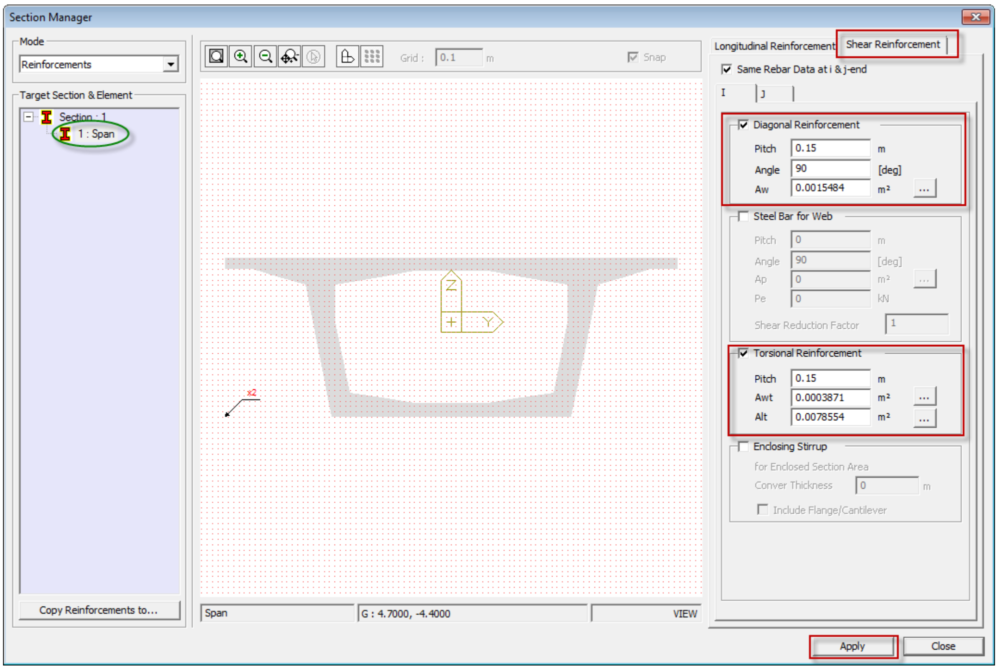


Fig. 10.2 Shear Reinforcement of PSC section

Modify Construction Stage Analysis Control Data to take into account the effect of re-bars in creep and shrinkage restraint. In case of a PSC section, we can consider rebars for the calculation of section properties of PSC Box.
We are now ready to perform the structural analysis.

Analysis / Construction Stage Analysis Control… / Time Dependent Effect Control
Consider Re-Bar Confinement Effect (on) ↵

Analysis / Main Control Data
Consider Reinforcement for Section Stiffness Calculation (on) ↵

Analysis / *Perform Analysis*

Consider the reinforcement entered into the PSC section for the calculation of section properties. If this option is checked off, the reinforcement will not be considered for calculation of section properties.

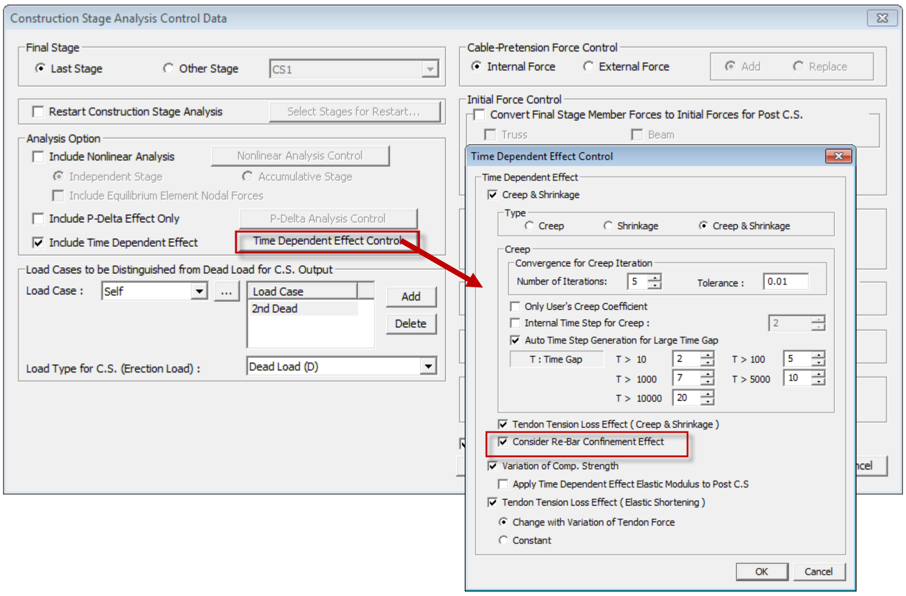
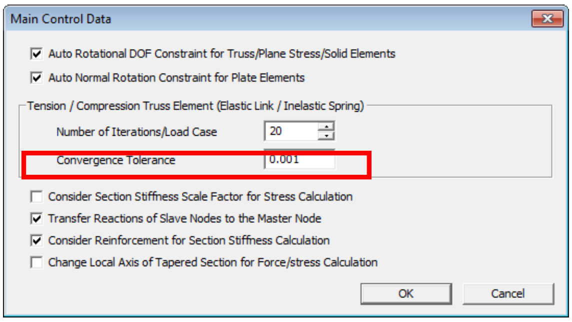


Fig.11 Input window of the Construction Stage Analysis Control Data



PSC Section Design

In this tutorial, we will learn how to check the stresses and the strengths of the PSC sections, using the analysis results.
In midas Civil, the PSC section check is performed after a series of tasks such as defining design parameters, load combinations, modifying material properties, selecting locations for the section check etc.

Define Design Parameters

Define the design parameters such as design standards, tendon type, bridge type, type of construction, corrosive condition and the method to compute flexural strength of PSC box girder.

In the case of "***Flexural Strength***", if **'Code'** is selected, the design standard is used to determine of flexural strength of PSC Box girder (AASHTO-LRFD 12, Clause 5.7.3.2). 'Strain Compatibility' method is provided for more precise calculation of flexural strength using strain compatibility approach.

The user can select different options in the "Output Parameters" depending upon the requirement.

PSC / Design Parameters / ***PSC Design Parameters…***
Input Parameters
Design Code: **AASHTO-LRFD 12**
Tendon Type: **Low Relaxation Tendons** (on)
Construction Type**: Segmental** (on)
Corrosive Condition: **Severe** (on)
Flexural Strength: **Code** (on)
Exposure Factor for Crack Width: **Class I (1.0)**
Output Parameters
Select All ↵

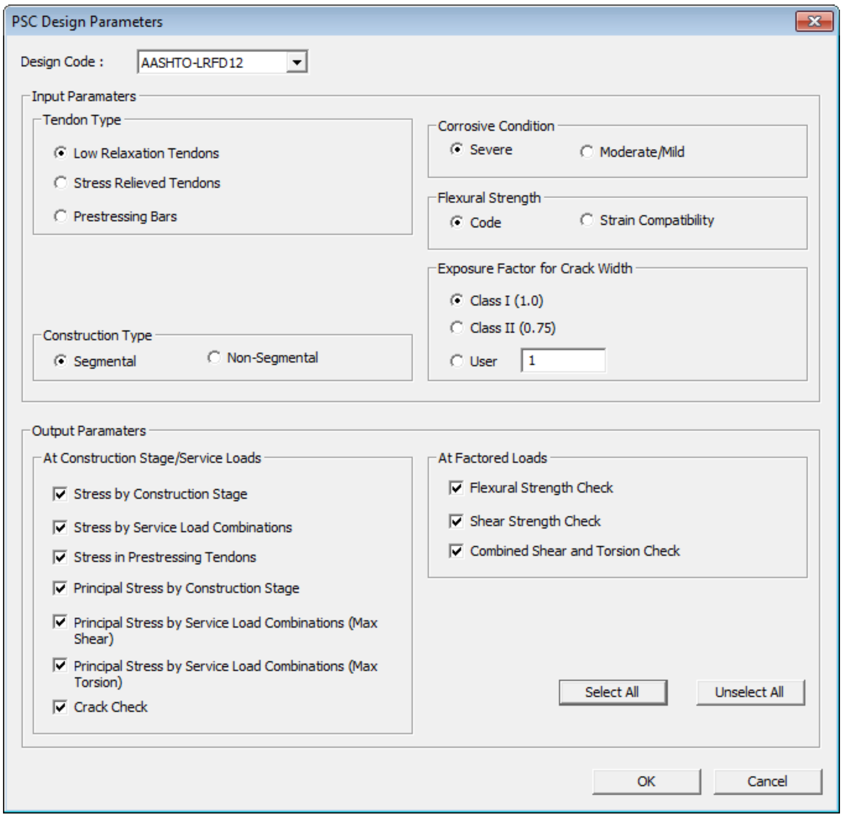


Fig. 13 Defining design parameter

Load Combination

We can generate load combinations for the PSC design based on Bridge Design Specification (AASHTO –LRFD 12),
In midas Civil, '***Auto Generation***' function automatically generates load combinations for ULS and SLS according to the design standard of user's requirement.
In this tutorial we will generate load combinations based on the Bridge Design Specification (AASHTO-LRFD 12).

If "CS Only" is selected, the program generates load combinations after construction stage analysis and it includes only construction stage load cases.

Results / Load Combination / ***Concrete Design/*** Auto Generation... ↵
Input parameter of the design calculation
Design Code > **AASHTO-LRFD 12**
Manipulation of Construction Stage Load Case> **CS Only**
Condition for Temperature **> All Other Effects** ↵

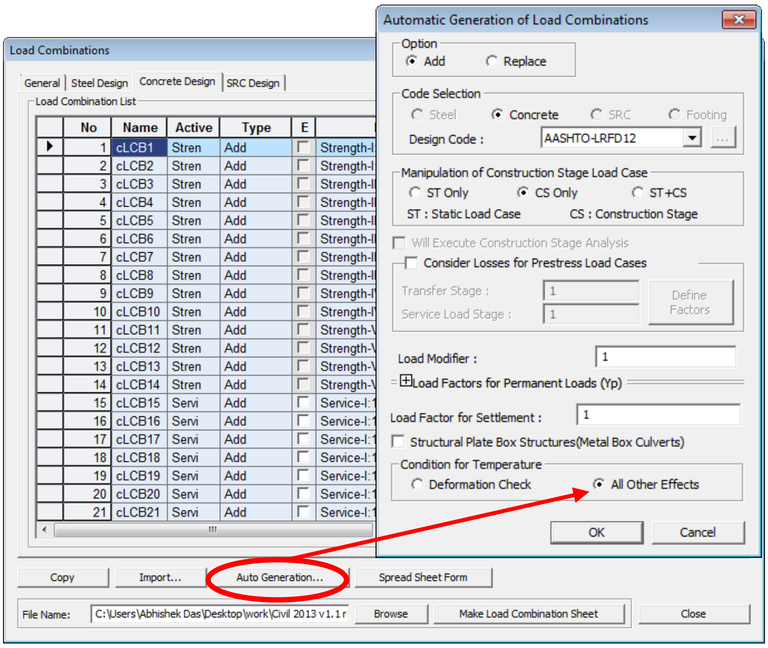


Fig.14 Load combination using Auto Generation

Tendon Primary load is not included in the flexural strength check. It is because Tendon Primary is considered while computing the nominal strength. Creep Secondary & Shrinkage Secondary are used for member force calculation. In midas Civil, Creep & Shrinkage Primary are used for finding displacement.

Modify material properties

This function is used to modify the properties of the steel rebar and the concrete material defined while creating analysis model. This modification will be used only for the designing and strength verification. The analysis results remain unaffected.
In this design example, concrete material is same i.e. C5000, we only need to specify the grades of Main rebar i.e. longitudinal steel and sub-rebar i.e. steel used for shear reinforcement.

PSC / PSC Design Data/ ***PSC Design Material…***

Material List> ID1

Concrete Material Selection

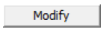
Code>**ASTM (RC)**

Grade>**C5000**

Rebar Selection

Code> **ASTM (RC)**

Grade of Main Rebar>**Grade 60;** Grade of Sub-Rebar>**Grade 60**



↵

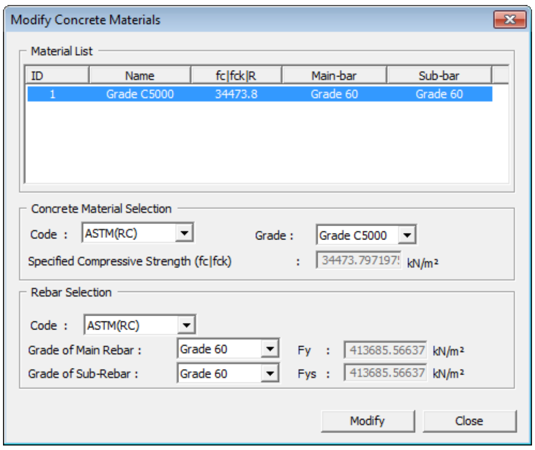


Fig. 15 Modify concrete and steel materials for design

Select Locations for PSC Design

Using this function we can select the elements and their ends (only I, only J or both I & J) to be checked for moment or shear or both, for PSC. If we do not select specific locations for check, both parts (I&J) of all the elements will be checked for both moment and shear.

PSC / PSC Design Data / ***Design/Output Option*** / ***Design Position…***

Option>Add/Replace

Select Elements by Identifying… (Element: **16, 17, 26, 27**)

Moment> **I &J** (on)

Shear> **None** (on)

Select Elements by Identifying… (Element: **1to2**)

Moment> **None** (on)

Shear> **I &J** (on) ↵

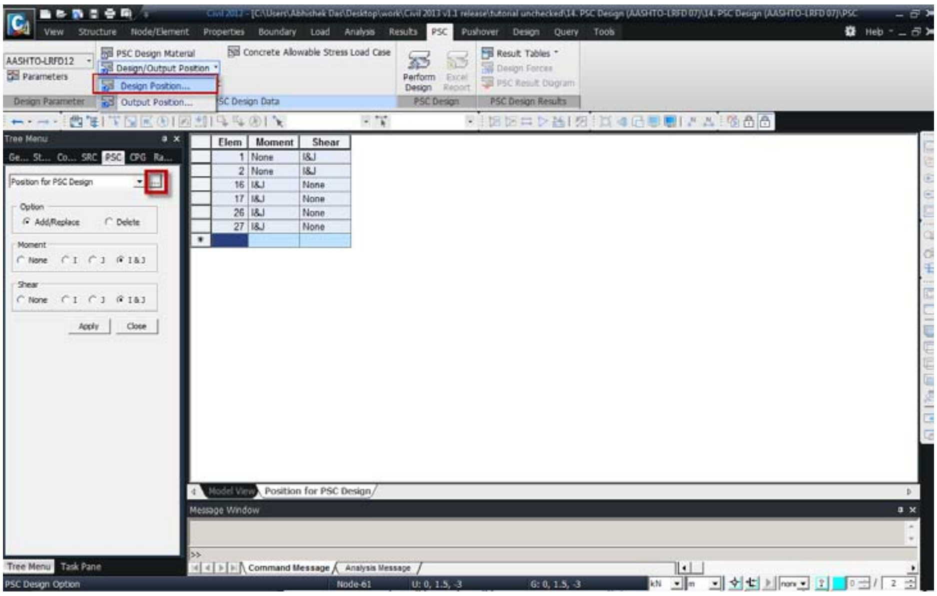


Fig.16 PSC Design option

We can check selected elements and locations in the Table and it is also possible to add, modify, and delete in the Table.

In the table, delete all elements which are selected for the check.

As mentioned, if location for the moment and shear check is not specified by the user, the program will automatically check I & J ends of all the elements.

It is convenient if we select 'PSC Design Option' of 'PSC Design' from 'Table Tab' in 'Tree View'.

PSC / PSC Design Data / ***Design/Output Option*** / ***Design Position…***

Then click on the square box just to the right of Position for PSC Design as shown Fig. 16

Select All> ***"Delete"*** ↵

Delete using "Delete" Key in the Keyboard

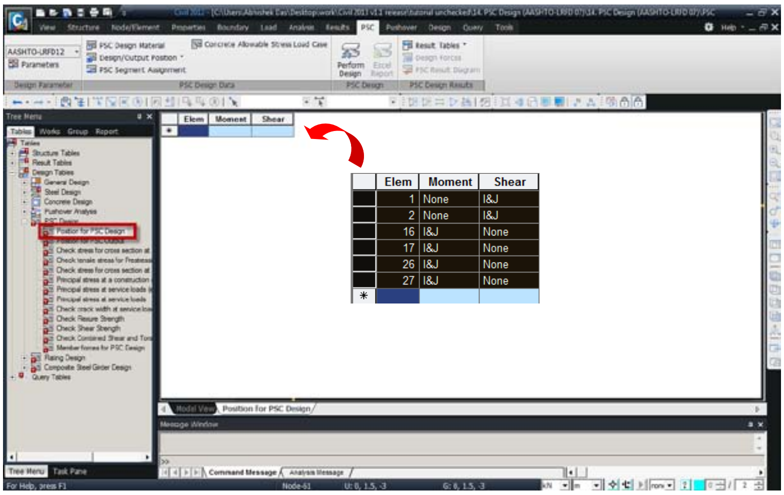


Fig. 17 PSC Design Option Table

Select location for output

Using this feature we can select the ends of elements for which flexural and (or) shear and (or) torsion strength are to be produced in output report (in excel sheet) generated from 'PSC Design Calculation' after PSC Design. It is important to note that output can be produced only for those elements which have been assigned PSC Design Option.
In the following example, we will print the flexure, shear and torsion strength of the elements in the central span and at support.

PSC / PSC Design Data / ***Design/Output Option*** / ***Output Position…***
Option>Add/Replace
Select Elements by Identifying… (Element: **16, 17, 26, 27, 35, 36**)
Moment Strength> M (+) >**I &J** (on)
Moment Strength> M (-) >**I &J** (on)
Shear Strength>**I &J** (on)
Torsion Strength>**I &J** (on) ↵

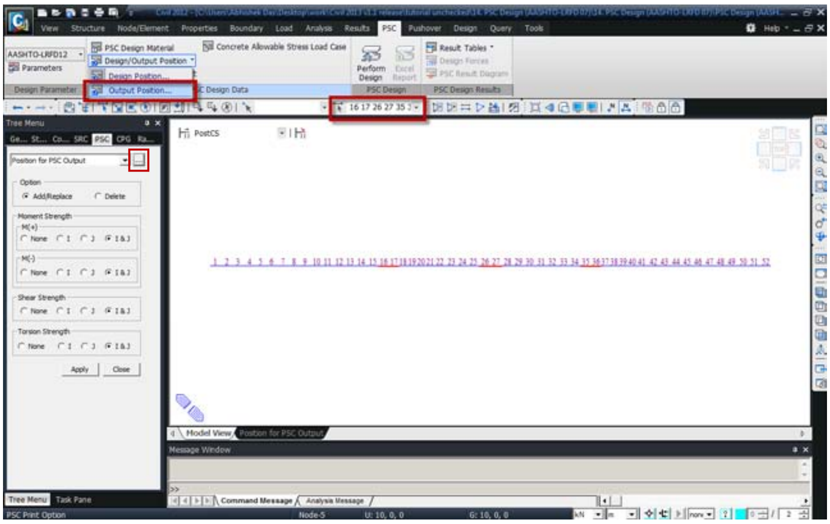


Fig. 18 PSC Print Option dialog box

We can check the selected elements and locations in the table and it is possible to add, modify and delete data in the table
If no element is selected in PSC Print Option, we won't get the flexural strength, shear strength and torsion strength of any element in the PSC Design Calculation report.

PSC / PSC Design Data / ***Design/Output Option*** / ***Output Position…***
Then click on the square box just to the right of Position for PSC Design as shown Fig. 18

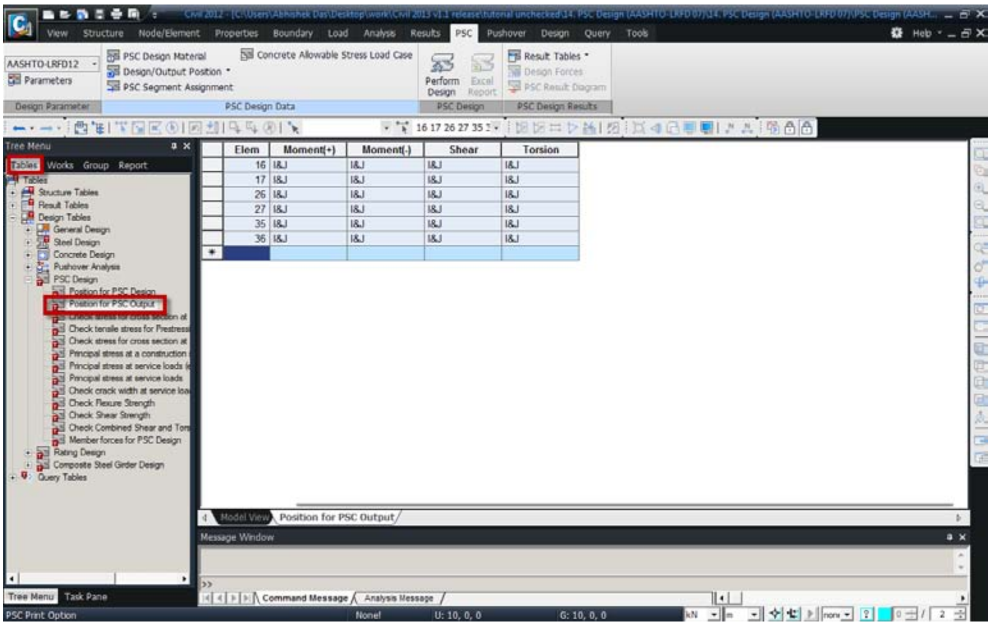


Fig. 19 PSC Output Position Option Table

PSC Segment Assignment

This feature enables the user to provide the location of joints for design. One segment consists of consecutively selected elements. I and J ends of each segment are considered as joint locations. Segment assignment is ignored if non-segmental option is selected in PSC Design Parameters. If the modeling is such that a segment is represented by single element, then no need to use this feature.

Concrete Allowable Stress Load Case

Using this option we can select which service load combinations to choose for stress checks in concrete. Compression in prestressed concrete segments is investigated using Service I loads and Service III loads are used to investigate tensile stresses in prestressed concrete components. We can assign various load combinations under Service I and Service III based on the stress check to be performed.

PSC / PSC Design Data / ***Concrete Allowable Stress Load Case***

Select the load combinations **cLCB15~cLCB22** and assign them under Service Limit I by clicking on the -> button just to the left of the Service Limit I box.
Select the load combinations **cLCB25~cLCB28** and assign them under Service Limit III by clicking on the -> button just to the left of the Service Limit III box.

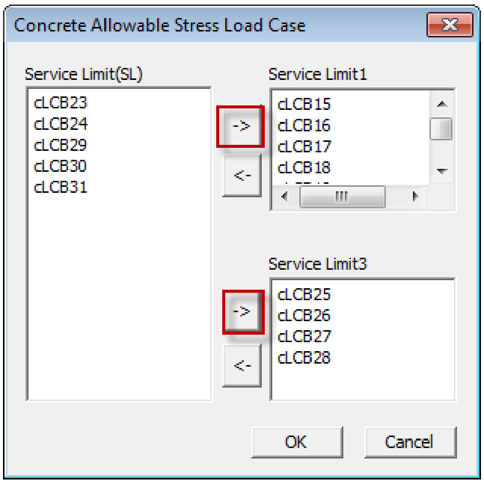


Fig. 20 Concrete Allowable Stress Load Case

PSC Section Design

Perform the PSC Design

PSC / PSC Design / ***PSC Design*** ↵

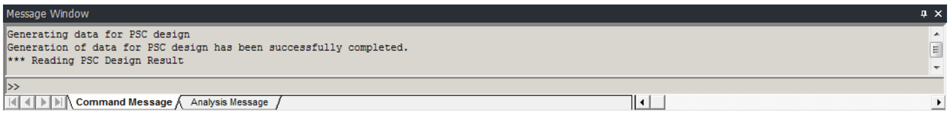


Fig. 20 Message after completing PSC Design

Design Results

We can see the design results in Tables (**PSC>PSC Design Results> Result Tables**). We can also check the design calculation in excel sheet format. This design result corresponds to the 'Input' and 'Output' parameters defined in 'PSC Design Parameters'.

PSC Design Calculation Excel Report

It produces PSC design results in excel format for the elements selected in PSC Print Option.
This sheet can be generated in Post CS stage and if the number of selected elements is larger, it takes longer time to generate the sheet.
The excel sheet is saved in the saved folder of model files (*.mcb).

PSC / PSC Design / ***Excel Report***↲

Check Design Result Tables

The results that can be checked have been categorized into two.
In the first category we can check the stresses at construction stages and at service load.
The second category corresponds to ultimate limit state check. Here we can perform Flexural strength check, Shear strength check and Combined Shear & Torsion Check at factored loads.

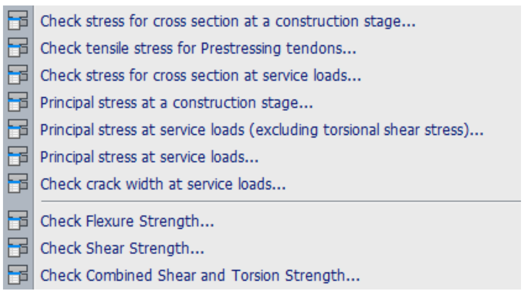


Fig. 21 PSC design result tables

Following sign convention is used for stresses

- Compression: (+)
- Tension: (-)

1. Check Stress for Cross Section at a Construction Stage

It checks the compression and tensile stresses for cross section at a construction stage. The checks are made as per the clauses 5.9.4.1.1 and 5.9.4.1.2 of AASHTO LFRD 12. Max/Min stress are shown for each part (I, J) of the elements, at the construction stages for which the stresses at that part are maximum.

Elem	Part	Comp./Tens.	Stage	CHK	FT (kips/in²)	FB (kips/in²)	FTL (kips/in²)	FBL (kips/in²)	FTR (kips/in²)	FBR (kips/in²)	FMAX (kips/in²)	ALW (kips/in²)
1	I[1]	Compression	CS1	OK	0.2623	0.9761	0.2623	0.9761	0.2623	0.9761	0.9761	2.6266
1	I[1]	Tension	CS1	OK	0.2623	0.9761	0.2623	0.9761	0.2623	0.9761	0.2623	-0.0000
1	J[2]	Compression	CS1	OK	0.3160	0.9272	0.3160	0.9272	0.3160	0.9272	0.9272	2.6266
1	J[2]	Tension	CS1	OK	0.3160	0.9272	0.3160	0.9272	0.3160	0.9272	0.3160	-0.0000
2	I[2]	Compression	CS1	OK	0.3160	0.9272	0.3160	0.9272	0.3160	0.9272	0.9272	2.6266
2	I[2]	Tension	CS1	OK	0.3160	0.9272	0.3160	0.9272	0.3160	0.9272	0.3160	-0.0000
2	J[3]	Compression	CS1	OK	0.3266	0.9466	0.3266	0.9466	0.3266	0.9466	0.9466	2.6266
2	J[3]	Tension	CS1	OK	0.3266	0.9466	0.3266	0.9466	0.3266	0.9466	0.3266	-0.0000
3	I[3]	Compression	CS1	OK	0.3266	0.9466	0.3266	0.9466	0.3266	0.9466	0.9466	2.6266

Description of each item in the above table is as follows

Elem	: Element No.	FTL	: Combined Stress due to bending moment about major axis (My), minor axis (Mz) and axial force at Top Left fiber.
Part	: Location(I, J)	FBL	: Combined Stress due to bending moment about major axis (My), minor axis (Mz) and axial force at Bottom Left fiber.
Comp/Tens	: Compression, Tension	FTR	: Combined Stress due to bending moment about major axis (My), minor axis (Mz) and axial force at Top Right fiber.
Stage	:Critical Construction Stage	FBR	: Combined Stress due to bending moment about major axis (My), minor axis (Mz) and axial force at Bottom Right fiber.
OK	:Stress check result, whether section is 'ok' or 'Not good'	FMAX	: Maximum combined stress out of the above six.
FT	:Combined Stress due to bending moment about major axis (My) and axial force at Top fiber.	ALW	: Allowable stress of cross section at construction stage as per AASHTO LRFD 12 5.9.4.1.1 & 5.9.4.1.2 clause.
FB	: Combined Stress due to bending moment about major axis (My) and axial force at Bottom fiber.		

2. Check Tensile Stress for Prestressing Tendons

It checks the tensile stresses for prestressing tendons. The check is made as per the clause 5.9.3 of AASHTO LRFD 12. The table presents the stresses according to Tendon Groups.

Tendon	FDL1 (kips/in²)	FDL2 (kips/in²)	FLL1 (kips/in²)	AFDL1 (kips/in²)	AFDL2 (kips/in²)	AFLL1 (kips/in²)
A1L	158.7288	175.3581	150.1238	192.9001	203.9230	185.6482
A1R	158.7288	175.3581	150.1238	192.9001	203.9230	185.6482
A2L	159.8690	176.0727	150.5707	192.9001	203.9230	185.6482
A2R	159.8690	176.0727	150.5707	192.9001	203.9230	185.6482
A3L	160.9504	176.8609	151.1673	192.9001	203.9230	185.6482
A3R	160.9504	176.8609	151.1673	192.9001	203.9230	185.6482
A4L	162.2412	177.5549	151.7947	192.9001	203.9230	185.6482
A4R	162.2412	177.5549	151.7947	192.9001	203.9230	185.6482
B1L	152.5057	172.2120	148.0084	192.9001	203.9230	185.6482
B1R	152.5057	172.2120	148.0084	192.9001	203.9230	185.6482
B2L	140.5745	166.7164	143.2241	192.9001	203.9230	185.6482
B2R	140.5745	166.7164	143.2241	192.9001	203.9230	185.6482
B3L	157.7343	175.0276	150.0857	192.9001	203.9230	185.6482
B3R	157.7343	175.0276	150.0857	192.9001	203.9230	185.6482
B4L	160.1953	176.1858	151.1967	192.9001	203.9230	185.6482
B4R	160.1953	176.1858	151.1967	192.9001	203.9230	185.6482
C1L	152.5037	172.2350	147.7836	192.9001	203.9230	185.6482
C1R	152.5037	172.2350	147.7836	192.9001	203.9230	185.6482
C2L	140.6066	166.7164	142.8821	192.9001	203.9230	185.6482
C2R	140.6066	166.7164	142.8821	192.9001	203.9230	185.6482
C3L	157.7309	175.0243	149.8191	192.9001	203.9230	185.6482
C3R	157.7309	175.0243	149.8191	192.9001	203.9230	185.6482
C4L	160.1953	176.1859	150.8616	192.9001	203.9230	185.6482
C4R	160.1953	176.1859	150.8616	192.9001	203.9230	185.6482

Description of each item in the above table is as follows

Tendon	: Tendon profile names.	AFDL1	: Allowable Stress in Tendon immediately after anchor set at anchorages.
FDL1	: Maximum stress in tendon along the length of the member away from anchorages, immediately after anchor set..	AFDL2	: Allowable stress in tendon immediately after anchor set elsewhere
FDL2	: Stress in tendon immediately after anchor set, elsewhere along the tendon length.	AFLL1	: Allowable stress in tendon at service limit state after losses
FLL1	: Maximum stress in tendon after all losses at the last stage..		

3. Check Stress for Cross Section at Service Loads

It checks the compression and tensile stress for cross section at service loads. This check is made as per the clause 5.9.4.2.1 and 5.9.4.2.2 of AASHTOLRFD 12. The table shows maximum compression and tensile stresses for each part of the elements along with the critical load combination (causing that stress).

	Elem	Part	Comp./Tens.	LCom Name	Type	CHK	FT (kips/in²)	FB (kips/in²)	FTL (kips/in²)	FBL (kips/in²)	FTR (kips/in²)	FBR (kips/in²)	FMAX (kips/in²)	ALW (kips/in²)
	8	J[9]	Compression	cLCB20	FX-MAX	OK	0.9389	0.2846	0.9263	0.2780	0.9514	0.2913	0.9514	2.2500
	8	J[9]	Tension	cLCB25	FX-MAX	NG	0.7787	-0.0315	0.7787	-0.0315	0.7787	-0.0315	-0.0315	-0.0000
	9	I[9]	Compression	cLCB20	FY-MAX	OK	0.9389	0.1257	0.9263	0.1191	0.9514	0.1324	0.9514	2.2500
	9	I[9]	Tension	cLCB25	FY-MAX	NG	0.7787	-0.0315	0.7787	-0.0315	0.7787	-0.0315	-0.0315	-0.0000
	9	J[10]	Compression	cLCB20	FY-MAX	OK	0.9333	0.1109	0.9225	0.1052	0.9440	0.1165	0.9440	2.2500
	9	J[10]	Tension	cLCB25	FY-MAX	NG	0.7565	-0.0224	0.7565	-0.0224	0.7565	-0.0224	-0.0224	-0.0000
	10	I[10]	Compression	cLCB20	FX-MAX	OK	0.9333	0.2697	0.9225	0.2641	0.9440	0.2754	0.9440	2.2500
	10	I[10]	Tension	cLCB25	FX-MAX	NG	0.7565	-0.0224	0.7565	-0.0224	0.7565	-0.0224	-0.0224	-0.0000
	10	J[11]	Compression	cLCB20	FX-MAX	OK	0.8942	0.2990	0.8861	0.2947	0.9024	0.3033	0.9024	2.2500

Description of each item in the above table is as follows

Element	: Element number.	FB	: Combined Stress due to bending moment about major axis (My) and axial force at Bottom fiber
Part	: Check location (I-End, J-End) of each element.	FTL	: Combined Stress due to bending moment about major axis (My), minor axis (Mz) and axial force at Top Left fiber
Comp./Tens	: Compression or Tension Stress.	FBL	: Combined Stress due to bending moment about major axis (My), minor axis (Mz) and axial force at Bottom Left fiber
Type	: Member force due to moving load, which causes the maximum stress.	FTR	: Combined Stress due to bending moment about major axis (My), minor axis (Mz) and axial force at Top Right fiber
LCom Name	: Load Combination Name	FBR	: Combined Stress due to bending moment about major axis (My), minor axis (Mz) and axial force at Bottom Right fiber
CHK	: Combined stress check for Service loads	FMAX	: Maximum combined stress out of the above six.
FT	: Combined Stress due to bending moment about major axis (My) and axial force at Top fiber.	ALW	: Allowable stress in concrete at service limit state as per AASHTO LRFD 12 5.9.4.2.1 & 5.9.4.2.2 clause

4. Principal Stress at Construction Stage

It checks the principal tensile stresses in the PSC section at a construction stage at which the Sig_Max is maximum at the given element. The allowable stresses are calculated as per table 5.14.2.3.3-1 of AASHTO-LRFD 2012.

🎧 **The checking location (Z1 & Z3) of the shear stress in the web can be specified under 'Shear Check' while defining PSC sections. And, if we check AUTO, the program will decide the level Z1 and Z3 automatically.**

Elem	Part	Comp./Tens.	Stage	CHK	Sig_P1 (kips/in²)	Sig_P2 (kips/in²)	Sig_P3 (kips/in²)	Sig_P4 (kips/in²)	Sig_P5 (kips/in²)	Sig_P6 (kips/in²)	Sig_P7 (kips/in²)	Sig_P8 (kips/in²)	Sig_P9 (kips/in²)	Sig_P10 (kips/in²)	Sig_MAX (kips/in²)	Sig_AP (kips/in²)
1	I[1]	Tension	CS4	OK	-0.0000	-0.0000	-0.0000	-0.0000	-0.0350	-0.0350	-0.0518	-0.0518	-0.0213	-0.0213	-0.0518	-0.2460
1	J[2]	Tension	CS4	OK	-0.0000	-0.0000	-0.0000	-0.0000	-0.0068	-0.0068	-0.0116	-0.0116	-0.0052	-0.0052	-0.0116	-0.2460
2	I[2]	Tension	CS4	OK	-0.0000	-0.0000	-0.0000	-0.0000	-0.0068	-0.0068	-0.0116	-0.0116	-0.0052	-0.0052	-0.0116	-0.2460
2	J[3]	Tension	CS4	OK	-0.0000	-0.0000	-0.0000	-0.0000	-0.0034	-0.0034	-0.0062	-0.0062	-0.0029	-0.0029	-0.0062	-0.2460
3	I[3]	Tension	CS4	OK	-0.0000	-0.0000	-0.0000	-0.0000	-0.0034	-0.0034	-0.0062	-0.0062	-0.0029	-0.0029	-0.0062	-0.2460
3	J[4]	Tension	CS4	OK	-0.0000	-0.0000	-0.0000	-0.0000	-0.0025	-0.0025	-0.0047	-0.0047	-0.0023	-0.0023	-0.0047	-0.2460
4	I[4]	Tension	CS4	OK	-0.0000	-0.0000	-0.0000	-0.0000	-0.0025	-0.0025	-0.0047	-0.0047	-0.0023	-0.0023	-0.0047	-0.2460
4	J[5]	Tension	CS4	OK	-0.0000	-0.0000	-0.0000	-0.0000	-0.0019	-0.0019	-0.0038	-0.0038	-0.0019	-0.0019	-0.0038	-0.2460
5	I[5]	Tension	CS4	OK	-0.0000	-0.0000	-0.0000	-0.0000	-0.0019	-0.0019	-0.0038	-0.0038	-0.0019	-0.0019	-0.0038	-0.2460
5	J[6]	Tension	CS4	OK	-0.0000	-0.0000	-0.0000	-0.0000	-0.0017	-0.0017	-0.0034	-0.0034	-0.0019	-0.0019	-0.0034	-0.2460
6	I[6]	Tension	CS4	OK	-0.0000	-0.0000	-0.0000	-0.0000	-0.0017	-0.0017	-0.0034	-0.0034	-0.0019	-0.0019	-0.0034	-0.2460
6	J[7]	Tension	CS2	OK	-0.0000	-0.0000	-0.0000	-0.0000	-0.0016	-0.0016	-0.0030	-0.0030	-0.0014	-0.0014	-0.0030	-0.2460
7	I[7]	Tension	CS2	OK	-0.0000	-0.0000	-0.0000	-0.0000	-0.0016	-0.0016	-0.0030	-0.0030	-0.0014	-0.0014	-0.0030	-0.2460
7	J[8]	Tension	CS2	OK	-0.0000	-0.0000	-0.0000	-0.0000	-0.0002	-0.0002	-0.0004	-0.0004	-0.0002	-0.0002	-0.0004	-0.2460
8	I[8]	Tension	CS2	OK	-0.0000	-0.0000	-0.0000	-0.0000	-0.0002	-0.0002	-0.0004	-0.0004	-0.0002	-0.0002	-0.0004	-0.2460
8	J[9]	Tension	CS4	OK	-0.0000	-0.0000	-0.0000	-0.0000	-0.0007	-0.0007	-0.0015	-0.0015	-0.0010	-0.0010	-0.0015	-0.2460
9	I[9]	Tension	CS4	OK	-0.0000	-0.0000	-0.0000	-0.0000	-0.0007	-0.0007	-0.0015	-0.0015	-0.0010	-0.0010	-0.0015	-0.2460
9	J[10]	Tension	CS4	OK	-0.0000	-0.0000	-0.0000	-0.0000	-0.0033	-0.0033	-0.0072	-0.0072	-0.0044	-0.0044	-0.0072	-0.2460
10	I[10]	Tension	CS4	OK	-0.0000	-0.0000	-0.0000	-0.0000	-0.0033	-0.0033	-0.0072	-0.0072	-0.0044	-0.0044	-0.0072	-0.2460
10	J[11]	Tension	CS4	OK	-0.0000	-0.0000	-0.0000	-0.0000	-0.0085	-0.0085	-0.0172	-0.0172	-0.0097	-0.0097	-0.0172	-0.2460

Description of each item in the above table is as follows.

Elem	: Element Number	Sig_P5	: Principal stress at the top of left web (at Z1 level).
Part	: Check location (I-End, J-End) of each element	Sig_P6	: Principal stress at the top of right web (at Z1 level).
Comp/Tens.	: Compression or Tension Stress	Sig_P7	: Principal stress at the neutral axis in left web (Z2 level).
Stage	: Construction Stage	Sig_P8	: Principal stress at the neutral axis of right web (at Z2 level).
CHK	: Principal stress check for construction stages	Sig_P9	: Principal stress at the bottom of left web (at Z3 level).
Sig_P1	: Principal stress at top-left of top flange	Sig_P10	: Principal stress at the bottom of right web(at Z3 level)
Sig_P2	: Principal stress at top-right of top flange	Sig_MAX	: Maximum of P1-P10
Sig_P3	: Principal stress at bottom-right of bottom flange	Sig_AP	: Allowable principal tensile stress at neutral axis in the web
Sig_P4	: Principal stress at bottom-left of bottom flange		

5. Principal Stress at Service Loads (excluding Torsional Shear Stress)

It checks principal tensile stresses in the PSC section at service loads (excluding shear stress due to torsion). The allowable stresses are calculated as per clause 5.9.4.2.2 of AASHTO-LRFD 2012.

The elements, for which the stress value is higher than the allowable stress, are shown in red colour.

	Elem	Part	Comp./Tens.	LCom Name	Type	CHK	Sig_P1 (kips/in²)	Sig_P2 (kips/in²)	Sig_P3 (kips/in²)	Sig_P4 (kips/in²)	Sig_P5 (kips/in²)	Sig_P6 (kips/in²)	Sig_P7 (kips/in²)	Sig_P8 (kips/in²)	Sig_P9 (kips/in²)	Sig_P10 (kips/in²)	Sig_MAX (kips/in²)	Sig_AP (kips/in²)
	1	I[1]	Tension	cLCB16	FZ-MIN	OK	-0.0034	-0.0034	-0.0037	-0.0037	-0.0644	-0.0964	-0.1859	-0.2297	-0.0251	-0.0820	-0.2297	-0.2460
	1	J[2]	Tension	cLCB16	FZ-MIN	OK	-0.0016	-0.0016	-0.0035	-0.0035	-0.0239	-0.0441	-0.0962	-0.1345	-0.0091	-0.0499	-0.1345	-0.2460
	2	I[2]	Tension	cLCB16	FZ-MIN	OK	-0.0016	-0.0016	-0.0035	-0.0035	-0.0239	-0.0441	-0.0960	-0.1343	-0.0069	-0.0386	-0.1343	-0.2460
	2	J[3]	Tension	cLCB31	FX-MAX	OK	-0.0021	-0.0021	-0.1255	-0.1255	-0.0013	-0.0062	-0.0057	-0.0204	-0.0960	-0.1036	-0.1255	-0.2460
	3	I[3]	Tension	cLCB31	FX-MAX	OK	-0.0021	-0.0021	-0.1255	-0.1255	-0.0013	-0.0062	-0.0057	-0.0204	-0.0960	-0.1036	-0.1255	-0.2460
	3	J[4]	Tension	cLCB31	FX-MAX	OK	-0.0013	-0.0013	-0.1617	-0.1617	-0.0004	-0.0052	-0.0015	-0.0221	-0.1210	-0.1291	-0.1617	-0.2460
	4	I[4]	Tension	cLCB31	FX-MAX	OK	-0.0013	-0.0013	-0.1617	-0.1617	-0.0004	-0.0052	-0.0015	-0.0221	-0.1210	-0.1291	-0.1617	-0.2460
	4	J[5]	Tension	cLCB31	FX-MAX	OK	-0.0009	-0.0009	-0.1895	-0.1896	-0.0000	-0.0052	-0.0035	-0.0250	-0.1405	-0.1496	-0.1896	-0.2460
	5	I[5]	Tension	cLCB31	FX-MAX	OK	-0.0009	-0.0009	-0.1895	-0.1895	-0.0000	-0.0052	-0.0035	-0.0250	-0.1405	-0.1496	-0.1895	-0.2460
	5	J[6]	Tension	cLCB31	FX-MAX	OK	-0.0008	-0.0008	-0.2096	-0.2096	-0.0001	-0.0060	-0.0080	-0.0291	-0.1548	-0.1653	-0.2096	-0.2460
	6	I[6]	Tension	cLCB31	FX-MAX	OK	-0.0008	-0.0008	-0.2096	-0.2096	-0.0001	-0.0060	-0.0080	-0.0291	-0.1548	-0.1653	-0.2096	-0.2460
	6	J[7]	Tension	cLCB31	FX-MAX	OK	-0.0007	-0.0007	-0.2218	-0.2218	-0.0003	-0.0070	-0.0125	-0.0333	-0.1634	-0.1755	-0.2218	-0.2460
	7	I[7]	Tension	cLCB31	FX-MAX	OK	-0.0007	-0.0007	-0.2218	-0.2218	-0.0003	-0.0070	-0.0125	-0.0333	-0.1634	-0.1755	-0.2218	-0.2460
	7	J[8]	Tension	cLCB31	FX-MAX	OK	-0.0007	-0.0007	-0.2251	-0.2252	-0.0008	-0.0085	-0.0171	-0.0377	-0.1655	-0.1796	-0.2252	-0.2460
	8	I[8]	Tension	cLCB31	FX-MAX	OK	-0.0007	-0.0007	-0.2251	-0.2252	-0.0008	-0.0085	-0.0171	-0.0377	-0.1655	-0.1796	-0.2252	-0.2460
	8	J[9]	Tension	cLCB31	FX-MAX	OK	-0.0007	-0.0007	-0.2217	-0.2217	-0.0015	-0.0104	-0.0218	-0.0423	-0.1626	-0.1790	-0.2217	-0.2460
	9	I[9]	Tension	cLCB31	FX-MAX	OK	-0.0007	-0.0007	-0.2217	-0.2217	-0.0015	-0.0104	-0.0218	-0.0423	-0.1626	-0.1790	-0.2217	-0.2460
	9	J[10]	Tension	cLCB31	FX-MAX	OK	-0.0007	-0.0007	-0.2108	-0.2108	-0.0025	-0.0128	-0.0264	-0.0470	-0.1541	-0.1737	-0.2108	-0.2460
	10	I[10]	Tension	cLCB31	FX-MAX	OK	-0.0007	-0.0007	-0.2108	-0.2108	-0.0025	-0.0128	-0.0264	-0.0470	-0.1541	-0.1737	-0.2108	-0.2460
	10	J[11]	Tension	cLCB31	FX-MAX	OK	-0.0008	-0.0008	-0.1921	-0.1922	-0.0039	-0.0161	-0.0310	-0.0517	-0.1398	-0.1635	-0.1922	-0.2460

Description of each item in the above table is as follows

Elem	: Element Number	Sig_P4	: Principal stress at bottom-left of bottom flange
Part	: Principal stress check for construction stages	Sig_P5	: Principal stress at the top of left web (at Z1 level).
Comp/Tens.	: Compression or Tension Stress	Sig_P6	: Principal stress at the top of right web (at Z1 level).
LCom. Name	: Load combination name	Sig_P7	: Principal stress at the neutral axis in left web (Z2 level).
Type	: Member force due to moving load, which causes the maximum stress.	Sig_P8	: Principal stress at the neutral axis of right web (at Z2 level).
CHK	: Principal stress check for service loads at maximum shear force.	Sig_P9	: Principal stress at the bottom of left web (at Z3 level).
Sig_P1	: Principal stress at top-left of top flange	Sig_P10	: Principal stress at the bottom of right web(at Z3 level)
Sig_P2	: Principal stress at top-right of top flange	Sig_MAX	: Maximum of P1-P10
Sig_P3	: Principal stress at bottom-right of bottom flange	Sig_AP	: Allowable principal tensile stress at neutral axis in the web

6. Principal stress at service loads

It checks principal tensile stresses at service loads.

Elem	Part	Comp./Tens.	LCom Name	Type	CHK	Sig_P1 (kips/in²)	Sig_P2 (kips/in²)	Sig_P3 (kips/in²)	Sig_P4 (kips/in²)	Sig_P5 (kips/in²)	Sig_P6 (kips/in²)	Sig_P7 (kips/in²)	Sig_P8 (kips/in²)	Sig_P9 (kips/in²)	Sig_P10 (kips/in²)	Sig_MAX (kips/in²)	Sig_AP (kips/in²)
1	I[1]	Tension	cLCB16	FZ-MIN	OK	-0.0034	-0.0034	-0.0037	-0.0037	-0.0644	-0.0964	-0.1859	-0.2297	-0.0251	-0.0820	-0.2297	-0.2460
1	J[2]	Tension	cLCB16	FZ-MIN	OK	-0.0016	-0.0016	-0.0035	-0.0035	-0.0239	-0.0441	-0.0962	-0.1345	-0.0091	-0.0499	-0.1345	-0.2460
2	I[2]	Tension	cLCB16	FZ-MIN	OK	-0.0016	-0.0016	-0.0035	-0.0035	-0.0239	-0.0441	-0.0960	-0.1343	-0.0069	-0.0386	-0.1343	-0.2460
2	J[3]	Tension	cLCB31	FX-MAX	OK	-0.0021	-0.0021	-0.1255	-0.1255	-0.0013	-0.0062	-0.0057	-0.0204	-0.0960	-0.1036	-0.1255	-0.2460
3	I[3]	Tension	cLCB31	FX-MAX	OK	-0.0021	-0.0021	-0.1255	-0.1255	-0.0013	-0.0062	-0.0057	-0.0204	-0.0960	-0.1036	-0.1255	-0.2460
3	J[4]	Tension	cLCB31	FX-MAX	OK	-0.0013	-0.0013	-0.1617	-0.1617	-0.0004	-0.0052	-0.0015	-0.0221	-0.1210	-0.1291	-0.1617	-0.2460
4	I[4]	Tension	cLCB31	FX-MAX	OK	-0.0013	-0.0013	-0.1617	-0.1617	-0.0004	-0.0052	-0.0015	-0.0221	-0.1210	-0.1291	-0.1617	-0.2460
4	J[5]	Tension	cLCB31	FX-MAX	OK	-0.0009	-0.0009	-0.1895	-0.1896	-0.0000	-0.0052	-0.0035	-0.0250	-0.1405	-0.1496	-0.1896	-0.2460
5	I[5]	Tension	cLCB31	FX-MAX	OK	-0.0009	-0.0009	-0.1895	-0.1895	-0.0000	-0.0052	-0.0035	-0.0250	-0.1405	-0.1496	-0.1895	-0.2460
5	J[6]	Tension	cLCB31	FX-MAX	OK	-0.0008	-0.0008	-0.2096	-0.2096	-0.0001	-0.0060	-0.0080	-0.0291	-0.1548	-0.1653	-0.2096	-0.2460
6	I[6]	Tension	cLCB31	FX-MAX	OK	-0.0008	-0.0008	-0.2096	-0.2096	-0.0001	-0.0060	-0.0080	-0.0291	-0.1548	-0.1653	-0.2096	-0.2460
6	J[7]	Tension	cLCB31	FX-MAX	OK	-0.0007	-0.0007	-0.2218	-0.2218	-0.0003	-0.0070	-0.0125	-0.0333	-0.1634	-0.1755	-0.2218	-0.2460
7	I[7]	Tension	cLCB31	FX-MAX	OK	-0.0007	-0.0007	-0.2218	-0.2218	-0.0003	-0.0070	-0.0125	-0.0333	-0.1634	-0.1755	-0.2218	-0.2460
7	J[8]	Tension	cLCB31	FX-MAX	OK	-0.0007	-0.0007	-0.2251	-0.2252	-0.0008	-0.0085	-0.0171	-0.0377	-0.1655	-0.1796	-0.2252	-0.2460
8	I[8]	Tension	cLCB31	FX-MAX	OK	-0.0007	-0.0007	-0.2251	-0.2252	-0.0008	-0.0085	-0.0171	-0.0377	-0.1655	-0.1796	-0.2252	-0.2460
8	J[9]	Tension	cLCB31	FX-MAX	OK	-0.0007	-0.0007	-0.2217	-0.2217	-0.0015	-0.0104	-0.0218	-0.0423	-0.1626	-0.1790	-0.2217	-0.2460
9	I[9]	Tension	cLCB31	FX-MAX	OK	-0.0007	-0.0007	-0.2217	-0.2217	-0.0015	-0.0104	-0.0218	-0.0423	-0.1626	-0.1790	-0.2217	-0.2460
9	J[10]	Tension	cLCB31	FX-MAX	OK	-0.0007	-0.0007	-0.2108	-0.2108	-0.0025	-0.0128	-0.0264	-0.0470	-0.1541	-0.1737	-0.2108	-0.2460
10	I[10]	Tension	cLCB31	FX-MAX	OK	-0.0007	-0.0007	-0.2108	-0.2108	-0.0025	-0.0128	-0.0264	-0.0470	-0.1541	-0.1737	-0.2108	-0.2460
10	J[11]	Tension	cLCB31	FX-MAX	OK	-0.0008	-0.0008	-0.1921	-0.1922	-0.0039	-0.0161	-0.0310	-0.0517	-0.1398	-0.1635	-0.1922	-0.2460

Description of each item in the above table is as follows.

Elem	: Element Number	Sig_P4	: Principal stress at bottom-left of bottom flange
Part	: Principal stress check for construction stages	Sig_P5	: Principal stress at the top of left web (at Z1 level).
Comp/Tens.	: Compression or Tension Stress	Sig_P6	: Principal stress at the top of right web (at Z1 level).
LCom. Name	: Load combination name	Sig_P7	: Principal stress at the neutral axis in left web (Z2 level).
Type	: Member force due to moving load, which causes the maximum stress.	Sig_P8	: Principal stress at the neutral axis of right web (at Z2 level).
CHK	: Principal stress check for service loads at maximum shear force.	Sig_P9	: Principal stress at the bottom of left web (at Z3 level).
Sig_P1	: Principal stress at top-left of top flange	Sig_P10	: Principal stress at the bottom of right web(at Z3 level)
Sig_P2	: Principal stress at top-right of top flange	Sig_MAX	: Maximum of P1-P10
Sig_P3	: Principal stress at bottom-right of bottom flange	Sig_AP	: Allowable principal tensile stress at neutral axis in the web

7. Check Flexural Strength

It checks and compares flexural strength of the PSC section against the factored moment. Flexural strength is calculated as per the clause 5.7.3.2 of AASHTO LRFD 12, given by the formula:

$$M_n = A_{ps}f_{ps}\left(d_p - \frac{a}{2}\right) + A_s f_y\left(d_s - \frac{a}{2}\right) - A'_s f'_y\left(d'_s - \frac{a}{2}\right) + 0.85f'_c(b - b_w)h_w\left(\frac{a}{2} - \frac{h_f}{2}\right)$$

The rebars in the compression zone are also considered for the calculation of flexural strength. Depending upon the user's input in PSC Design Parameters for flexural strength, strain compatibility method can also be used for precise calculation of flexural strength.

Elem	Part	Positive/ Negative	LCom Name	Type	CHK	Muy (in·kips)	Mcr (in·kips)	Mny (in·kips)	PhiMny (in·kips)	Ratio (Muy/PhiMny)	PhiMny/ min(1.33Muy,Mcr)
1	I[1]	Negative	cLCB6	FX-MAX	OK	-227076.0536	493682.0073	356969.8621	356969.8621	0.6361	1.1820
1	I[1]	Positive	cLCB1	FZ-MAX	OK	0.0000	511389.1285	567789.8004	567789.8004	0.0000	13488239426.1981
1	J[2]	Negative	cLCB6	FX-MIN	OK	-153954.3021	455830.2332	287685.5127	287685.5127	0.5351	1.4050
1	J[2]	Positive	cLCB1	FX-MAX	OK	132144.4026	560731.9023	640127.0759	640127.0759	0.2064	3.6422
2	I[2]	Negative	cLCB6	FX-MIN	OK	-153954.5191	455830.2911	287685.5127	287685.5127	0.5351	1.4050
2	I[2]	Positive	cLCB1	FX-MAX	OK	132144.4026	560732.1665	640127.0759	640127.0759	0.2064	3.6422
2	J[3]	Negative	cLCB6	FX-MIN	OK	-126993.6033	416287.5052	217597.9401	217597.9401	0.5836	1.2883
2	J[3]	Positive	cLCB1	FX-MAX	OK	237232.2684	614861.0123	714699.2130	714699.2130	0.3319	2.2652
3	I[3]	Negative	cLCB6	FX-MIN	OK	-126993.9267	416287.5287	217597.9401	217597.9401	0.5836	1.2883
3	I[3]	Positive	cLCB1	FX-MAX	OK	237232.2684	614861.3618	714699.2130	714699.2130	0.3319	2.2652
3	J[4]	Negative	cLCB6	FX-MIN	OK	-110518.7913	383810.0755	163728.0522	163728.0522	0.6750	1.1139
3	J[4]	Positive	cLCB1	FX-MAX	OK	322993.5015	663645.6034	773894.3744	773894.3744	0.4174	1.8015
4	I[4]	Negative	cLCB6	FX-MIN	OK	-110519.1136	383810.0665	163728.0522	163728.0522	0.6750	1.1139
4	I[4]	Positive	cLCB1	FX-MAX	OK	322993.5015	663645.9315	773894.3744	773894.3744	0.4174	1.8015
4	J[5]	Negative	cLCB6	FX-MIN	NG	-99176.4777	359339.7835	126881.2240	126881.2240	0.7816	0.9619
4	J[5]	Positive	cLCB1	FX-MAX	OK	389587.4583	703001.2748	816132.4850	816132.4850	0.4774	1.5751
5	I[5]	Negative	cLCB6	FX-MIN	NG	-99176.7447	359339.7611	126881.2240	126881.2240	0.7817	0.9619

Description of each item in the above table is as follows.

Elem	: Element number	Muy	: Factored moment acting at section about y axis
Part	: Check location (I-End, J-End) of each element.	Mcr	: Cracking moment of the section
Positive/ Negative	: Positive/Negative Moment	Mny	: Nominal moment of resistance of section about y axis
LCom Name	:Load combination name corresponding to maximum and minimum value	PhiMny	: Factored moment of resistance of section about y axis. (Phi assumed as 1.0)
Type	: Member force due to moving load, which causes the maximum stress.	PhiMny /1.33Muy	:Ratio of factored moment of resistance to 1.33 times factored moment acting on the section about y axis
CHK	: Flexural strength check for element.	PhiMny /1.2Mcr	: Ratio of factored moment of resistance to 1.2 times cracking moment of the section.

8. Check Shear Strength

It checks the shear strength of the PSC section. Shear resistance is computed as per the section 5.8 of AASHTO LRFD 12.

Shear stress on concrete is determined by:

$$v_u = \frac{|V_u - \varphi V_p|}{\varphi b_v d_v}$$

Nominal Shear resistance is calculated as:

i) For post-tensioned segmental box girder bridges:

Vn is given by lesser of the two (Clause 5.8.6.5):

$$1. V_n = V_c + V_s$$

where,

$$V_c = 0.0632K\sqrt{f'_c} b_v d_v$$

$$V_s = \frac{A_v f_y d_v(\cot\theta + \cot\alpha)\sin\alpha}{s}$$

$$2. V_n = 0.379\sqrt{f'_c b_v d_v}$$

Note: Check for appropriate concrete section dimension (Eq. 5.8.6.5-5, AASHTO-LRFD 12) is not done as this doesn't correspond to strength of the section.

ii) For non-segmental bridges:

Vn is given by lesser of the two (Clause 5.8.3.3):

$$1. V_n = V_c + V_s + V_p$$

where,

$$V_c = 0.0316\beta\sqrt{f'_c} b_v d_v$$

$$2. V_n = 0.25 f'_c b_v d_v + V_p$$

	Elem	Part	Max/Min	LCom Name	Type	CHK	Vu (kips)	Mu (in-kips)	Vn (kips)	Phi	Vc (kips)	Vs (kips)	Vp (kips)	PhiVn (kips)	de (in)	dv (in)	ex	theta	beta	Avs (in^2)	Ast (in^2)	Al (in^2)	bv (in)	Avs_min	Avs_req	Al_min	bv_min (in)
	1	I[1]	Max	cLCB2	FZ-MAX	NG	-974.9	0.0000	778.71	0.9000	428.97	0.0000	349.73	700.83	69.282	94.488	0.0	0.0	0.0	0.0	0.0	0.0	32.126	0.0	0.0	0.0	13.480
	1	I[1]	Min	cLCB1	FZ-MIN	NG	-1518.	0.0000	778.71	0.9000	428.97	0.0000	349.73	700.83	69.282	94.488	0.0	0.0	0.0	0.0	0.0	0.0	32.126	0.0	0.0	0.0	19.167
	1	J[2]	Max	cLCB6	FX-MIN	OK	-480.0	-1539	826.16	0.9000	428.97	0.0000	397.18	743.54	42.921	94.488	0.0	0.0	0.0	0.0	0.0	0.0	32.126	0.0	0.0	0.0	8.7540
	1	J[2]	Min	cLCB1	FZ-MIN	NG	-1192.	87471.	826.16	0.9000	428.97	0.0000	397.18	743.54	77.194	94.488	0.0	0.0	0.0	0.0	0.0	0.0	32.126	0.0	0.0	0.0	16.203
	2	I[2]	Max	cLCB6	FX-MIN	OK	-480.0	-1539	826.16	0.9000	428.97	0.0000	397.18	743.54	42.921	94.488	0.0	0.0	0.0	0.0	0.0	0.0	32.126	0.0	0.0	0.0	8.7540
	2	I[2]	Min	cLCB1	FZ-MIN	NG	-1192.	87471.	826.16	0.9000	428.97	0.0000	397.18	743.54	77.194	94.488	0.0	0.0	0.0	0.0	0.0	0.0	32.126	0.0	0.0	0.0	16.203
	2	J[3]	Max	cLCB6	FX-MIN	OK	-330.9	-1269	785.43	0.9000	428.97	0.0000	356.45	706.88	34.668	94.488	0.0	0.0	0.0	0.0	0.0	0.0	32.126	0.0	0.0	0.0	6.8131
	2	J[3]	Min	cLCB1	FZ-MIN	NG	-1023.	15473	785.43	0.9000	428.97	0.0000	356.45	706.88	85.424	94.488	0.0	0.0	0.0	0.0	0.0	0.0	32.126	0.0	0.0	0.0	14.046
	3	I[3]	Max	cLCB6	FX-MIN	OK	-330.9	-1269	785.43	0.9000	428.97	0.0000	356.45	706.88	34.668	94.488	0.0	0.0	0.0	0.0	0.0	0.0	32.126	0.0	0.0	0.0	6.8131
	3	I[3]	Min	cLCB1	FZ-MIN	NG	-1023.	15473	785.43	0.9000	428.97	0.0000	356.45	706.88	85.424	94.488	0.0	0.0	0.0	0.0	0.0	0.0	32.126	0.0	0.0	0.0	14.046
	3	J[4]	Max	cLCB6	FX-MIN	OK	-279.0	-1105	703.54	0.9000	428.97	0.0000	274.57	633.19	32.154	94.488	0.0	0.0	0.0	0.0	0.0	0.0	32.126	0.0	0.0	0.0	5.4995
	3	J[4]	Min	cLCB1	FZ-MIN	NG	-855.0	20940	703.54	0.9000	428.97	0.0000	274.57	633.19	91.982	94.488	0.0	0.0	0.0	0.0	0.0	0.0	32.126	0.0	0.0	0.0	11.017
	4	I[4]	Max	cLCB6	FX-MIN	OK	-279.0	-1105	703.54	0.9000	428.97	0.0000	274.57	633.19	32.154	94.488	0.0	0.0	0.0	0.0	0.0	0.0	32.126	0.0	0.0	0.0	5.4995
	4	I[4]	Min	cLCB1	FZ-MIN	NG	-855.0	20940	703.54	0.9000	428.97	0.0000	274.57	633.19	91.982	94.488	0.0	0.0	0.0	0.0	0.0	0.0	32.126	0.0	0.0	0.0	11.017
	4	J[5]	Max	cLCB6	FX-MIN	OK	-239.3	-9917	616.34	0.9000	428.97	0.0000	187.36	554.71	26.597	94.488	0.0	0.0	0.0	0.0	0.0	0.0	32.126	0.0	0.0	0.0	4.2642
	4	J[5]	Min	cLCB1	FZ-MIN	NG	-688.9	25148	626.08	0.9000	438.71	0.0000	187.36	563.47	96.669	96.632	0.0	0.0	0.0	0.0	0.0	0.0	32.126	0.0	0.0	0.0	8.1440
	5	I[5]	Max	cLCB6	FX-MIN	OK	-239.3	-9917	616.34	0.9000	428.97	0.0000	187.36	554.71	26.597	94.488	0.0	0.0	0.0	0.0	0.0	0.0	32.126	0.0	0.0	0.0	4.2642
	5	I[5]	Min	cLCB1	FZ-MIN	NG	-688.9	25148	626.08	0.9000	438.71	0.0000	187.36	563.47	96.669	96.632	0.0	0.0	0.0	0.0	0.0	0.0	32.126	0.0	0.0	0.0	8.1440

Description of each item in the above table is as follows.

Elem	: Element number	de	:Effective depth from extreme compression fiber to centroid of the tensile force in the tensile reinforcement
Part	: Check location (I-End, J-End) of each element	dv	:Effective shear depth
Max/Min	: Maximum shear, minimum shear	ex	:Longitudinal strain in the web of the member
LCom Name	:Load combination name corresponding to maximum and minimum value	theta	:Angle of inclination of diagonal compressive stresses
Type	: Member force due to moving load, which causes the maximum stress.	beta	:Factor relating effect of the longitudinal strain on the shear capacity of the concrete, as indicated by the ability of diagonally cracked concrete to transmit tension
CHK	: Shear strength check for element.	Avs	:Area of transverse reinforcement within distance s
Vu	: Factored shear at section	Ast	:Total area of longitudinal mild steel reinforcement
Mu	:Factored moment at the section	Al	:Area of longitudinal torsion reinforcement in the exterior web of the box girder
Vn	:Nominal shear resistance at section	bv	:Width of web adjusted for the presence of ducts
Phi	:Resistance Factor	Avs_min	:Minimum area of the transverse reinforcement required within distance s
Vc	:Nominal shear resistance of concrete	Avs_reqd	:Area of transverse reinforcement required within distance s
Vs	: Shear resistance provided by transverse (shear) reinforcement.	Al_min	:Minimum area of longitudinal torsion reinforcement in the exterior web of the box girder required
Vp	:Component of the effective prestressing force in the direction of applied shear, positive if resisting shear	bv_min	:Minimum width of the web adjusted for the presence of the ducts required
PhiVn	:Factored shear resistance		

9. Check Combined Shear and Torsion Strength

It checks the combined shear and torsion strength of the PSC section. Combined Shear and Torsion check is done as per Clause 5.8.6.4 for Segmental box girder bridges and Clause 5.8.3.6.2 for other bridges.

Nominal torsional resistance, $T_n = \dfrac{2A_0A_tf_y}{s}\cot\theta$

Area of additional longitudinal reinforcement, $A_l = \dfrac{T_uPh}{2\varphi A_0f_y}$

Elem	Part	Max/Min	LCom Name	Type	CHK	Vu (kips)	Mu (in-kip	Tu (in-kip	Vn (kips)	Tn (in-ki	Phi	Phi_t	Vc (kips)	Vs (kips)	Vp (kips)	PhiVn (kips)	Phi_tTn	de (in)	dv (in)	ex	theta	beta	Avs (in²)	Ast (in²)	Al (in²)	bv (in)	Avs_min	Avs_req	Al_min (in²)
1	I[1]	T-Max	cLCB2	MX-MIN	NG	-1463.8	0.000	-243	778.7	0.0	0.9	0.900	428.9	0.000	349.7	700.8	0.000	69.28	94.48	0.0	0.0	0.0	0.0	0.0	0.0	32.1260	0.00	0.00	7.6575
1	I[1]	V-Max	cLCB2	MY-MAX	NG	-974.92	0.000	2435	778.7	0.0	0.9	0.900	428.9	0.000	349.7	700.8	0.000	69.28	94.48	0.0	0.0	0.0	0.0	0.0	0.0	32.1260	0.00	0.00	7.6575
1	I[1]	V-Min	cLCB1	MY-MIN	NG	-1518.9	0.000	-243	778.7	0.0	0.9	0.900	428.9	0.000	349.7	700.8	0.000	69.28	94.48	0.0	0.0	0.0	0.0	0.0	0.0	32.1260	0.00	0.00	7.6575
1	J[2]	T-Max	cLCB2	MY-MIN	NG	-1137.6	8204	-222	826.1	0.0	0.9	0.900	428.9	0.000	397.1	743.5	0.000	77.19	94.48	0.0	0.0	0.0	0.0	0.0	0.0	32.1260	0.00	0.00	7.0101
1	J[2]	V-Max	cLCB6	MZ-MAX	NG	-480.02	-153	-614	826.1	0.0	0.9	0.900	428.9	0.000	397.1	743.5	0.000	42.92	94.48	0.0	0.0	0.0	0.0	0.0	0.0	32.1260	0.00	0.00	1.9311
1	J[2]	V-Min	cLCB1	MZ-MIN	NG	-1192.7	8747	-222	826.1	0.0	0.9	0.900	428.9	0.000	397.1	743.5	0.000	77.19	94.48	0.0	0.0	0.0	0.0	0.0	0.0	32.1260	0.00	0.00	7.0101
2	I[2]	T-Max	cLCB2	MY-MIN	NG	-1137.6	8204	-222	826.1	0.0	0.9	0.900	428.9	0.000	397.1	743.5	0.000	77.19	94.48	0.0	0.0	0.0	0.0	0.0	0.0	32.1260	0.00	0.00	7.0101
2	I[2]	V-Max	cLCB6	MZ-MAX	NG	-480.02	-153	-614	826.1	0.0	0.9	0.900	428.9	0.000	397.1	743.5	0.000	42.92	94.48	0.0	0.0	0.0	0.0	0.0	0.0	32.1260	0.00	0.00	1.9310
2	I[2]	V-Min	cLCB1	MZ-MIN	NG	-1192.7	8747	-222	826.1	0.0	0.9	0.900	428.9	0.000	397.1	743.5	0.000	77.19	94.48	0.0	0.0	0.0	0.0	0.0	0.0	32.1260	0.00	0.00	7.0101
2	J[3]	T-Max	cLCB2	MY-MIN	NG	-967.85	1438	-203	785.4	0.0	0.9	0.900	428.9	0.000	356.4	706.8	0.000	85.42	94.48	0.0	0.0	0.0	0.0	0.0	0.0	32.1260	0.00	0.00	6.3819
2	J[3]	V-Max	cLCB6	MZ-MAX	NG	-330.99	-126	-526	785.4	0.0	0.9	0.900	428.9	0.000	356.4	706.8	0.000	34.66	94.48	0.0	0.0	0.0	0.0	0.0	0.0	32.1260	0.00	0.00	1.6537
2	J[3]	V-Min	cLCB1	MZ-MIN	NG	-1023.0	1547	-203	785.4	0.0	0.9	0.900	428.9	0.000	356.4	706.8	0.000	85.42	94.48	0.0	0.0	0.0	0.0	0.0	0.0	32.1260	0.00	0.00	6.3819
3	I[3]	T-Max	cLCB1	MY-MAX	NG	-615.44	2372	2030	785.4	0.0	0.9	0.900	428.9	0.000	356.4	706.8	0.000	85.42	94.48	0.0	0.0	0.0	0.0	0.0	0.0	32.1260	0.00	0.00	6.3819
3	I[3]	V-Max	cLCB6	MZ-MAX	NG	-330.99	-126	-526	785.4	0.0	0.9	0.900	428.9	0.000	356.4	706.8	0.000	34.66	94.48	0.0	0.0	0.0	0.0	0.0	0.0	32.1260	0.00	0.00	1.6549
3	I[3]	V-Min	cLCB1	MZ-MIN	NG	-1023.0	1547	-203	785.4	0.0	0.9	0.900	428.9	0.000	356.4	706.8	0.000	85.42	94.48	0.0	0.0	0.0	0.0	0.0	0.0	32.1260	0.00	0.00	6.3819
3	J[4]	T-Max	cLCB2	MY-MIN	NG	-799.89	1931	-183	703.5	0.0	0.9	0.900	428.9	0.000	274.5	633.1	0.000	91.98	94.48	0.0	0.0	0.0	0.0	0.0	0.0	32.1260	0.00	0.00	5.7729
3	J[4]	V-Max	cLCB6	MZ-MAX	NG	-279.02	-110	-438	703.5	0.0	0.9	0.900	428.9	0.000	274.5	633.1	0.000	32.15	94.48	0.0	0.0	0.0	0.0	0.0	0.0	32.1260	0.00	0.00	1.3777

Description of each item in the above table is as follows.

Elem	: Element number	Phi-tTn	: Factored torsional resistance
Part	: Check location (I-End, J-End) of each element	de	:Effective depth from extreme compression fibre to centroid of the tensile force in the tensile reinforcement
Max/Min	:Maximum/Minimum torsion/shear	dv	:Effective shear depth
LCom Name	:Load combination corresponding to maximum and minimum value	ex	:Longitudinal strain in the web of the member
Type	: Member force due to moving load, which causes the maximum stress.	theta	:Angle of inclination of diagonal compressive stresses
CHK	: Shear strength check for element.	beta	:Factor relating effect of the longitudinal strain on the shear capacity of the concrete, as indicated by the ability of diagonally cracked concrete to transmit tension
Vu	: Factored shear at section	Avs	:Area of transverse reinforcement within distance s
Tu	: Factored torsional moment at section.	Ast	:Total area of longitudinal mild steel reinforcement
Mu	:Factored moment at the section	Al	:Area of longitudinal torsion reinforcement in the exterior web of the box girder
Vn	:Nominal shear resistance at section	bv	:Width of web adjusted for the presence of ducts

Tn	: Nominal torsional resistance at section.	Avs_min	:Minimum area of the transverse reinforcement required within distance s
Phi	:Resistance Factor	Avs_reqd	:Area of transverse reinforcement required within distance s
Phi-t	: Resistance factor for torsion.	Al_min	:Minimum area of longitudinal torsion reinforcement in the exterior web of the box girder required
Vc	:Nominal shear resistance provided by tensile stresses in concrete	bv_min	:Minimum width of the web adjusted for the presence of the ducts required
Vs	:Shear resistance provided by shear stresses in concrete	At	:Total area of transverse torsion reinforcement in the exterior web of cellular members
Vp	:Component in the direction of applied shear of the effective prestressing force, positive if resisting shear	At_req	:Total area of transverse torsion reinforcement in the exterior web of cellular members required
PhiVn	:Factored shear resistance		

PSC Design Forces

This feature returns the design forces for each element under different load combination in spreadsheet format table. The table shows concurrent member forces namely Fx, Fy, Fz, Mx, My and Mz for all the elements under all load combinations.

PSC / PSC Design Results / ***Design Forces***↵

Elem	Part	LCom Name	Type	Fx (kips)	Fy (kips)	Fz (kips)	Mx (in·kips)	My (in·kips)	Mz (in·kips)
1	I	cLCB1	FX-MAX	-0.0749	0.0496	-1030.0746	24358.6940	0.0000	25.7261
1	I	cLCB1	FX-MIN	-0.6503	-0.0497	-1463.8488	-24358.6943	0.0000	-25.7261
1	I	cLCB1	FY-MAX	-0.0749	0.0496	-1030.0746	24358.6940	0.0000	25.7261
1	I	cLCB1	FY-MIN	-0.6503	-0.0497	-1463.8488	-24358.6943	0.0000	-25.7261
1	I	cLCB1	FZ-MAX	-0.1372	0.0496	-974.9317	24358.6940	0.0000	25.7261
1	I	cLCB1	FZ-MIN	-0.5879	-0.0497	-1518.9916	-24358.6943	0.0000	-25.7261
1	I	cLCB1	MX-MAX	-0.0749	0.0496	-1030.0746	24358.6940	0.0000	25.7261
1	I	cLCB1	MX-MIN	-0.6503	-0.0497	-1463.8488	-24358.6943	0.0000	-25.7261
1	I	cLCB1	MY-MAX	-0.1372	0.0496	-974.9317	24358.6940	0.0000	25.7261
1	I	cLCB1	MY-MIN	-0.5879	-0.0497	-1518.9916	-24358.6943	0.0000	-25.7261
1	I	cLCB1	MZ-MAX	-0.0962	0.0496	-1011.2174	24358.6940	0.0000	25.7261
1	I	cLCB1	MZ-MIN	-0.6290	-0.0497	-1482.7059	-24358.6943	0.0000	-25.7261
1	I	cLCB2	FX-MAX	-0.0749	0.0496	-1030.0722	24358.6940	0.0000	25.7261
1	I	cLCB2	FX-MIN	-0.6503	-0.0497	-1463.8464	-24358.6943	0.0000	-25.7261
1	I	cLCB2	FY-MAX	-0.0749	0.0496	-1030.0722	24358.6940	0.0000	25.7261
1	I	cLCB2	FY-MIN	-0.6503	-0.0497	-1463.8464	-24358.6943	0.0000	-25.7261
1	I	cLCB2	FZ-MAX	-0.1372	0.0496	-974.9294	24358.6940	0.0000	25.7261
1	I	cLCB2	FZ-MIN	-0.5879	-0.0497	-1518.9892	-24358.6943	-0.0000	-25.7261

Description of each item in the above table is as follows.

Elem	: Element number	Fy	: Design Shear force at the element end along y axis
Part	: Check location (I-End, J-End) of each element	Fz	: Design Shear force at the element end along z axis
LCom Name	: Load Combination corresponding to maximum and minimum value	Mx	: Design torsional moment at the element end
Type	: Member force due to moving load, which causes the maximum stress.	My	: Design moment at the element end due to bending about y axis.
Fx	: Design axial force at the element end	Mz	: Design moment at the element end due to bending about z axis.

PSC Design Result Diagram

This feature enables users to check result diagrams in contours. We can see the member force diagrams along with the nominal strength diagram.

There is only 'All COMBINATION' in case of PSC

If 'Safety factor' is chosen, the program displays the ratio diagram of design forces to strengths.

PSC / PSC Design Results/ ***PSC Result Diagram*** ↵
Load Cases/Combinations> **All COMBINATION**
Option>**Force**
Components> **Flexure-y**
Max, Min
Diagram Option
Scale Factor > **2**
Fill Type > **Solid** ↵

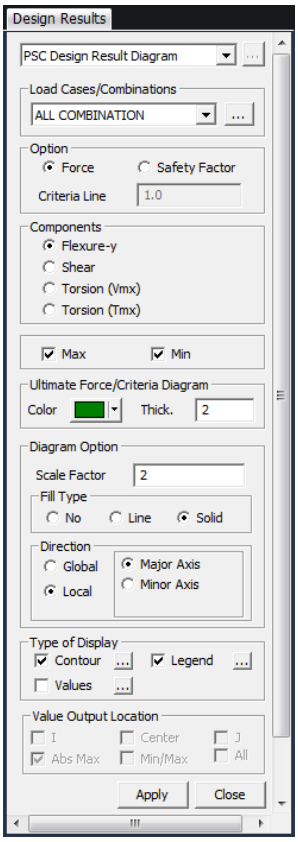


Fig. 22 PSC Design Result Diagram Dialog

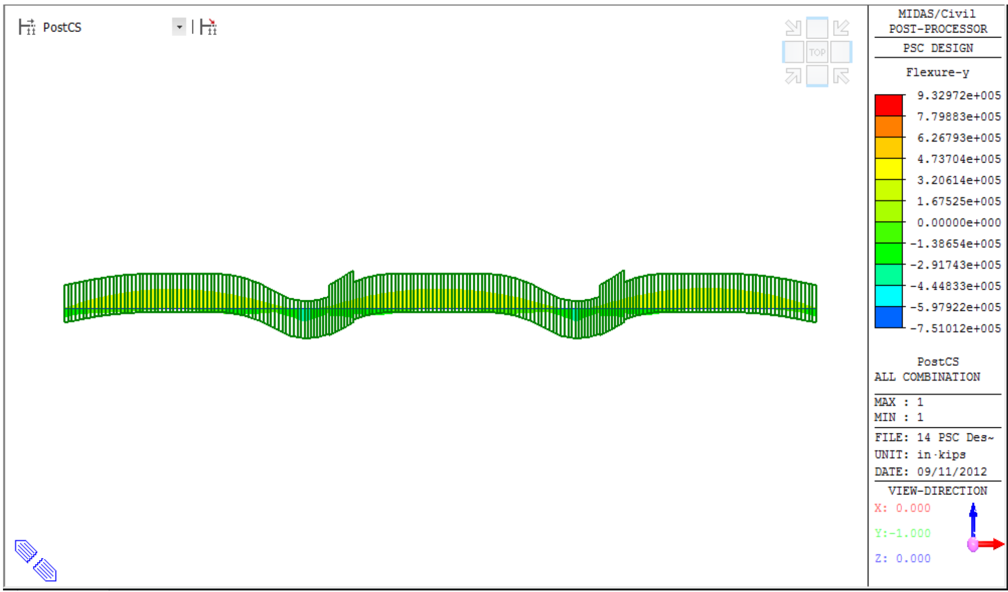


Fig. 23 PSC Design Result Diagram