Advanced Application

Prestressed Box Girder Design as per EN1992-2:05

Civil

Prestressed Box Girder Design

Overview

Design procedure for PSC section is as follows.

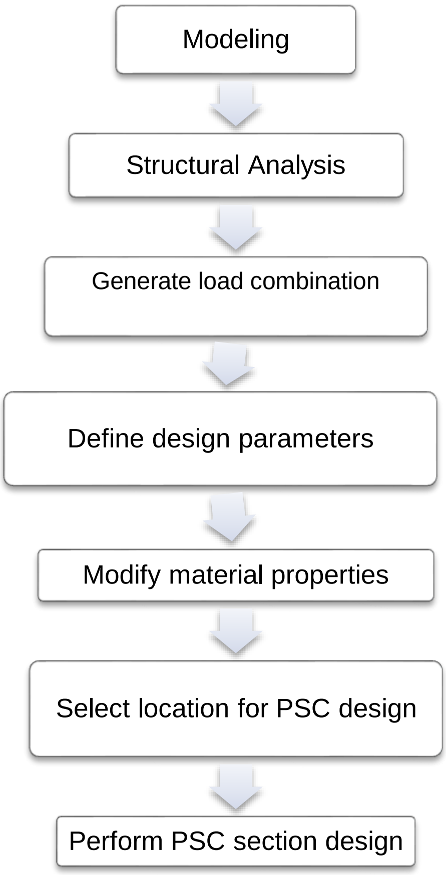


Fig.1 Procedure for PSC section design

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*).

3. Material definition should be from Eurocode database only.
4. Only PSC type section can be designed.

We will use an already modeled bridge. The bridge is a precast segmental bridge which has been constructed by Full Staging Method.

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)

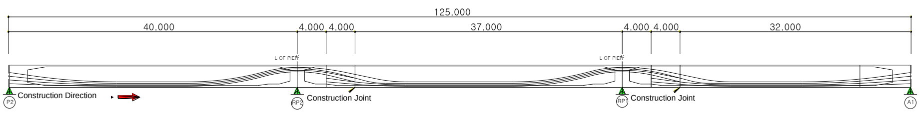


Fig. 2 Longitudinal section view Unit: m

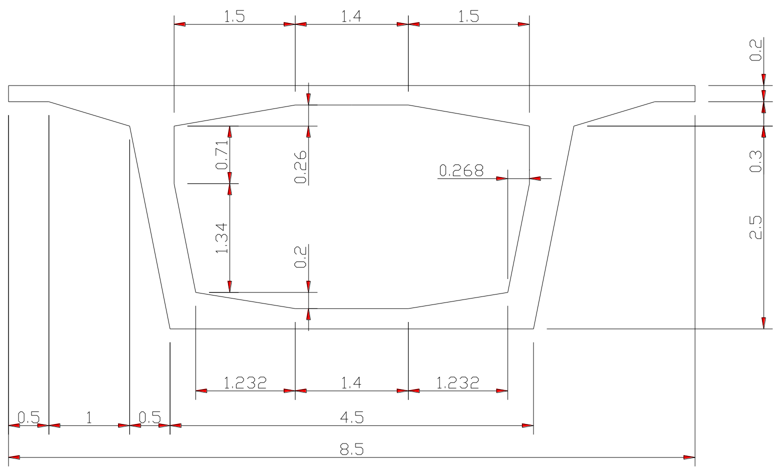
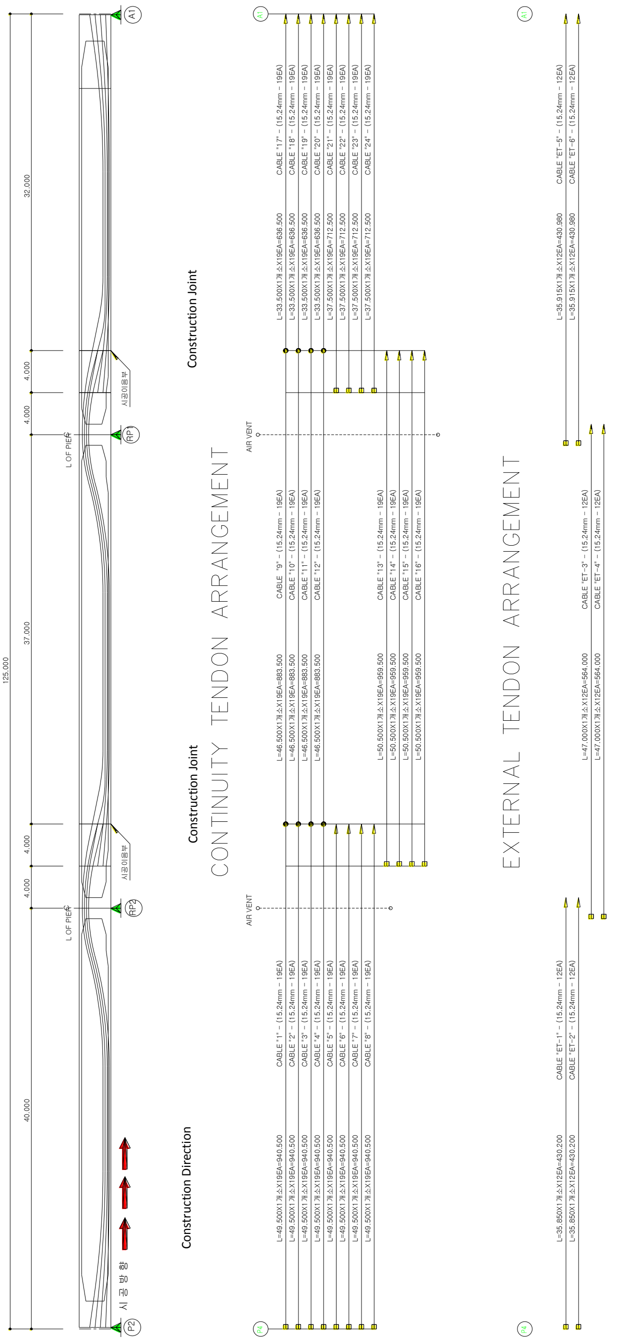


Fig. 3 Typical cross section Unit: m



Unit: m

Fig.4 Tendon Profile

Material Properties

- **Concrete properties for superstructure**
  EC (RC) Grade: C40/50

- **Tendon Properties**
  Material: EN 05(S) Y1770S7
  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
  Duct Diameter = 103 mm
  Modulus of Elasticity: E_{ps} = 1.95 X 10^5 N/mm^2
  Jacking Stress: f_{pj} = 0.7f_{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)

Load

- **Dead Load**
  Self-weight
  Input Self-Weight
  Superimposed dead load
  w = 35.796 kN/m

- **Pre Stress**
  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} = 0.7f_{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: Δl_c = 6 mm
  Elastic Shortening Loss: $\Delta P_E = \Delta f_P . A_{SP}$

Steel Relaxation (European)

Creep and Shrinkage Loss (European)

- **Creep and Shrinkage**

  Code: European

  Characteristic compressive strength of concrete at the age of 28 days : 48 N/mm^2.

  Relative Humidity of ambient environment: 70%

  Notational size of member: 364 mm.

  Type of cement: Class N.

  Type of code: EN 1992-2 (Concrete Bridge)

  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 : Load Model 1

  B. Psi Factor : LM1 Tandem **:** **0.75**

  LM1 UDL**:** **0.4**

- **Distribution of Lanes**

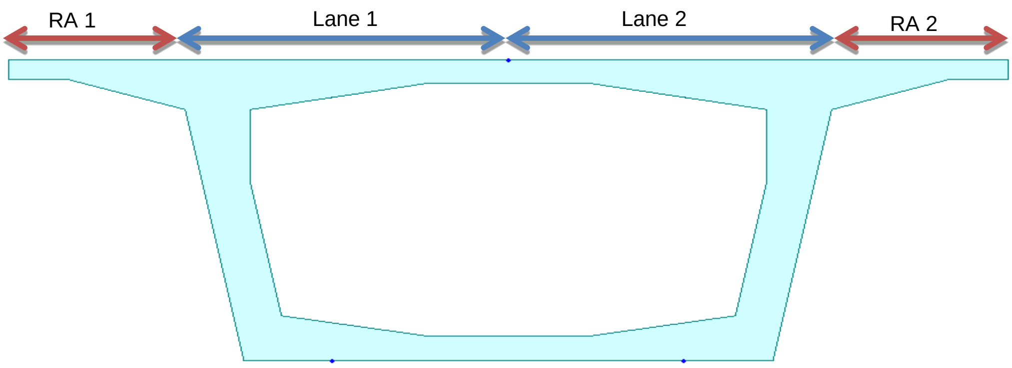


Fig.5 Lane Distribution for Moving load

- **Support Settlement**

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

- **Temperature Loads**

  Temperature difference (approach 2 in EN 1991-1-5)

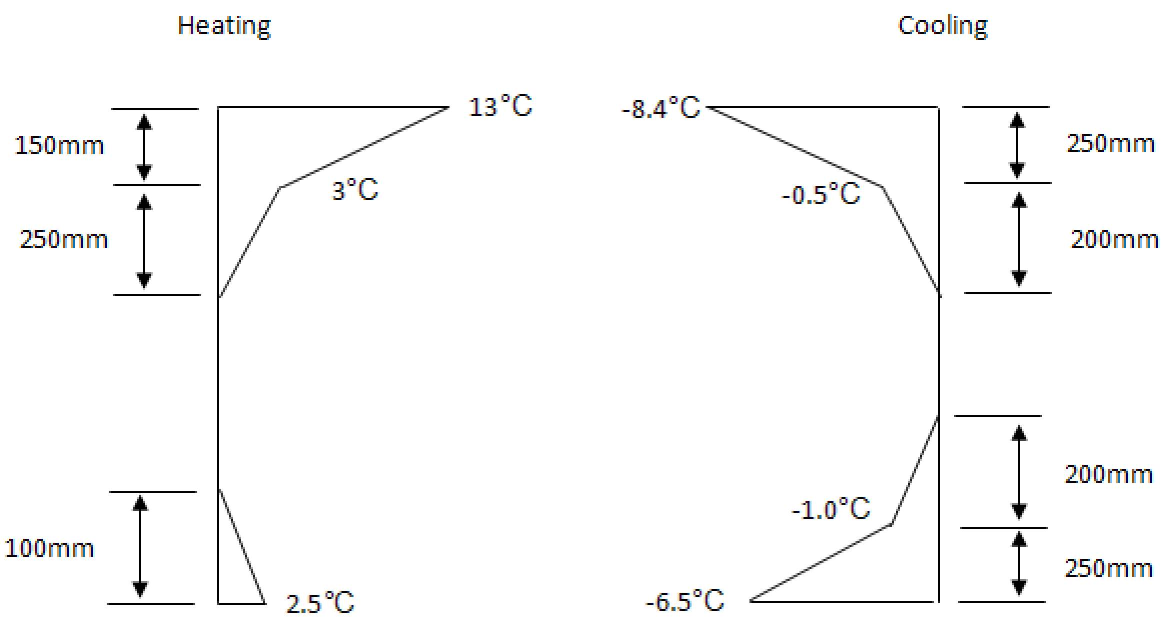


Fig.6 Vertical Temperature Difference

- **Wind Loads**

  Wind Load: 3 kN/m^2

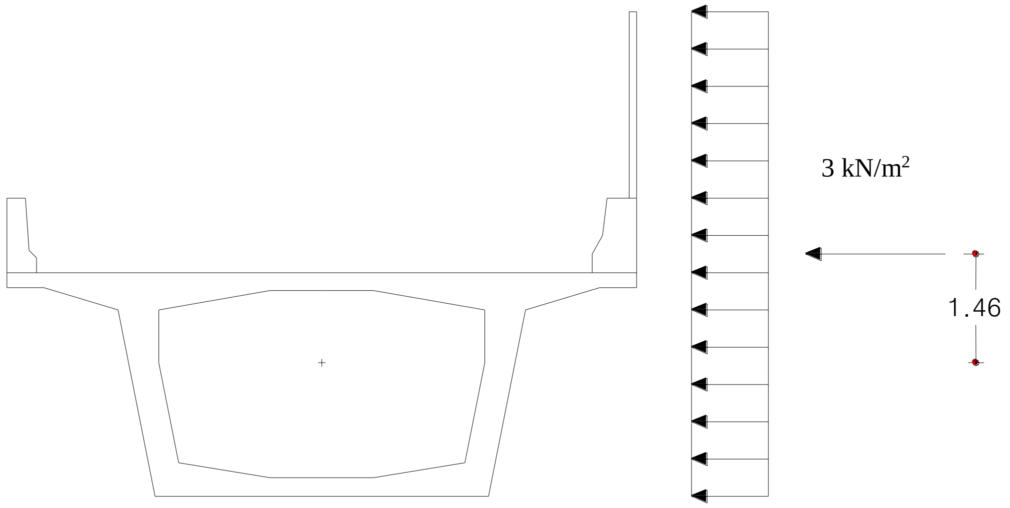


Fig. 7 Wind Load Distribution

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***) '20 PSC Design (Eurocode)_start model'.mcb.

File > ***Open Project***

Check the model data

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

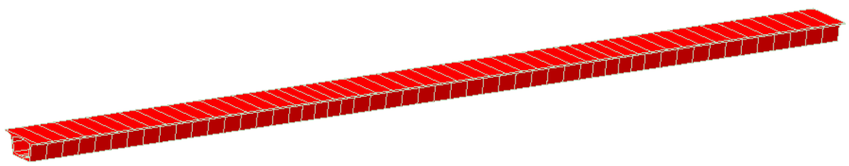


Fig. 8 FSM model used for section check

Reinforcement Input

In this tutorial, the arrangement of longitudinal rebar's has been simplified for convenience.

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

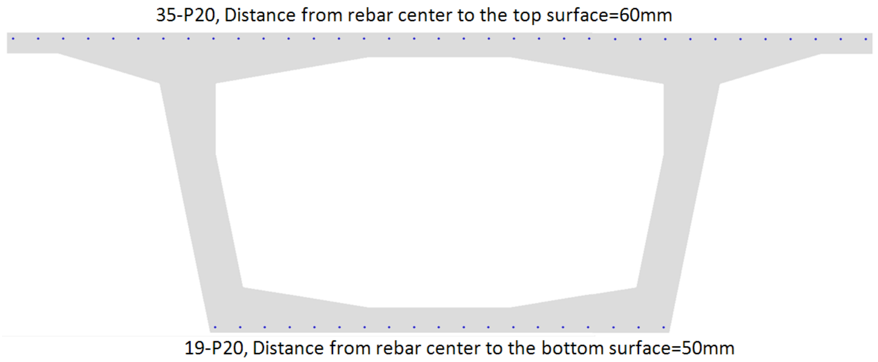


Fig. 9 Reinforcement in longitudinal direction

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-P12)
Torsion reinforcement	Pitch	0.15 m
	Awt	0.0003871m^2 (1-P10)
	Alt	0.0078554m^2 (62-P12)

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
Alt is the total area of longitudinal torsion reinforcement distributed around the perimeter of the closed stirrups.

Properties > Section Manager > ***Reinforcements***

Section List>**Span**

Longitudinal reinforcement

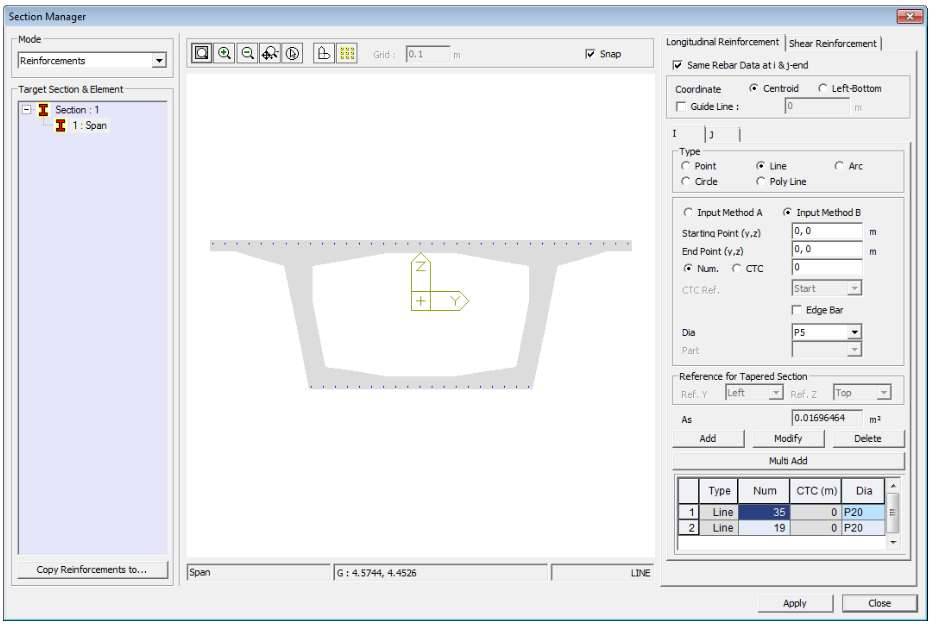
1. Type: Line, Input Method B, Starting Point **(-4.19, 1.14941)**, End Point **(4.19, 1.14941)**, Num. **(35)**, Check on **(Edge Bar)**, Dia **(P20)**
   Click **[Add]** button.
2. Type: Line, Input Method B, Starting Point **(-2.2, -1.74059)**, End Point **(2.2, -1.74059)**, Num. **(19)**, Check on **(Edge Bar)**, Dia **(P20)**
   Click **[Add]** button

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 "Both end parts (i & j) have the same reinforcement", the reinforcement data of one part will be copied to another.



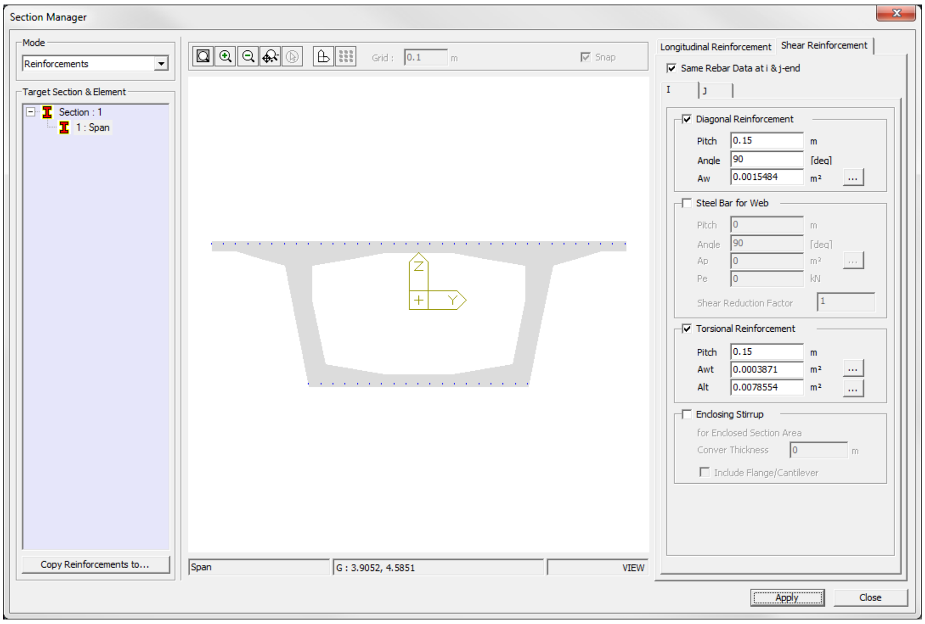


Fig. 10 Reinforcement of PSC section

Construction Stage Analysis Control & Perform Analysis

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…
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.

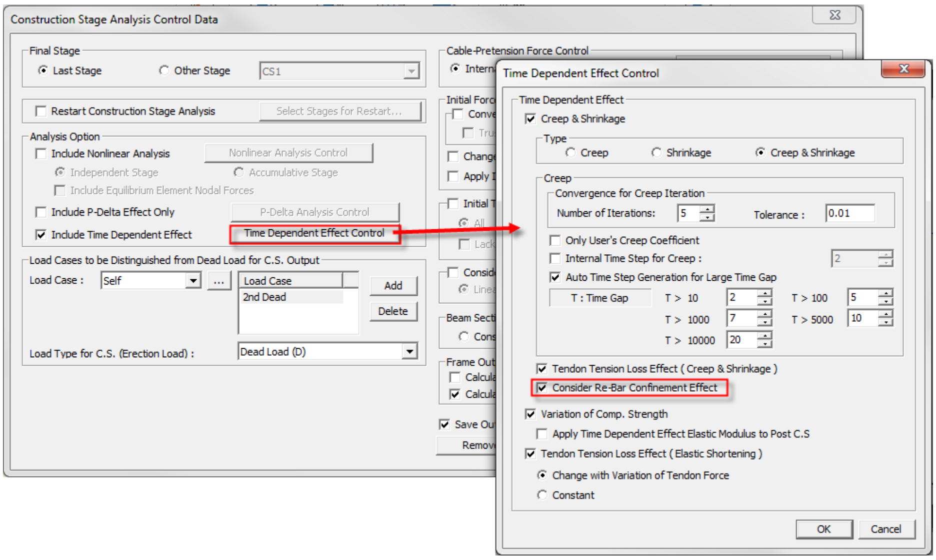


Fig.11 Input window of the Construction Stage Analysis Control Data

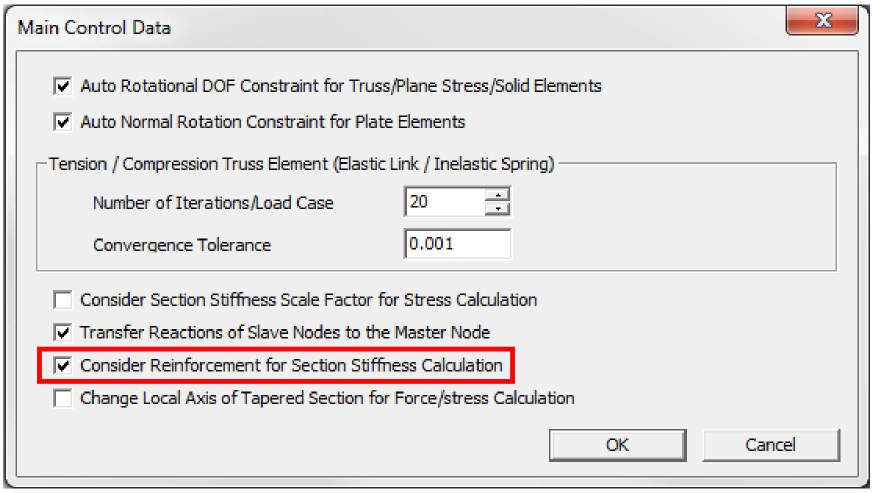


Fig.12 Main Control Data dialog box

Load Combination

In this tutorial we will generate the following load combinations based on the Bridge Design Specification (EUROCODE).

ULS
1.35Gk + P + 1.35(TS+UDL) + 1.5(0.6Fwk)
1.35Gk + P + 1.5Tk + 1.35(0.75TS+0.4UDL)
1.35Gk + P + 1.5Fwk

SLS
Characteristic
Gk + P + (TS+UDL) + (0.6Fwk)
Gk + P + Tk + (0.75TS+0.4UDL)
Gk + P + Fwk

Frequent
Gk + P + (0.75TS+0.4UDL)+ (0.5Tk)
Gk + P + (0.6Tk)
Gk + P + (0.2Fwk)

Quasi-permanent
Gk + P + (0.5Tk)

Tendon Primary load is not included in the **load combinations for ultimate limit state check**. It is because Tendon Primary is considered while computing the **bending resistance of cross-section**. Creep Secondary and Shrinkage Secondary are used for member force calculation. In midas Civil, Creep & Shrinkage Primary are used for finding displacement.

Result > Combination > ***Concrete Design>***
Define load combinations manually.

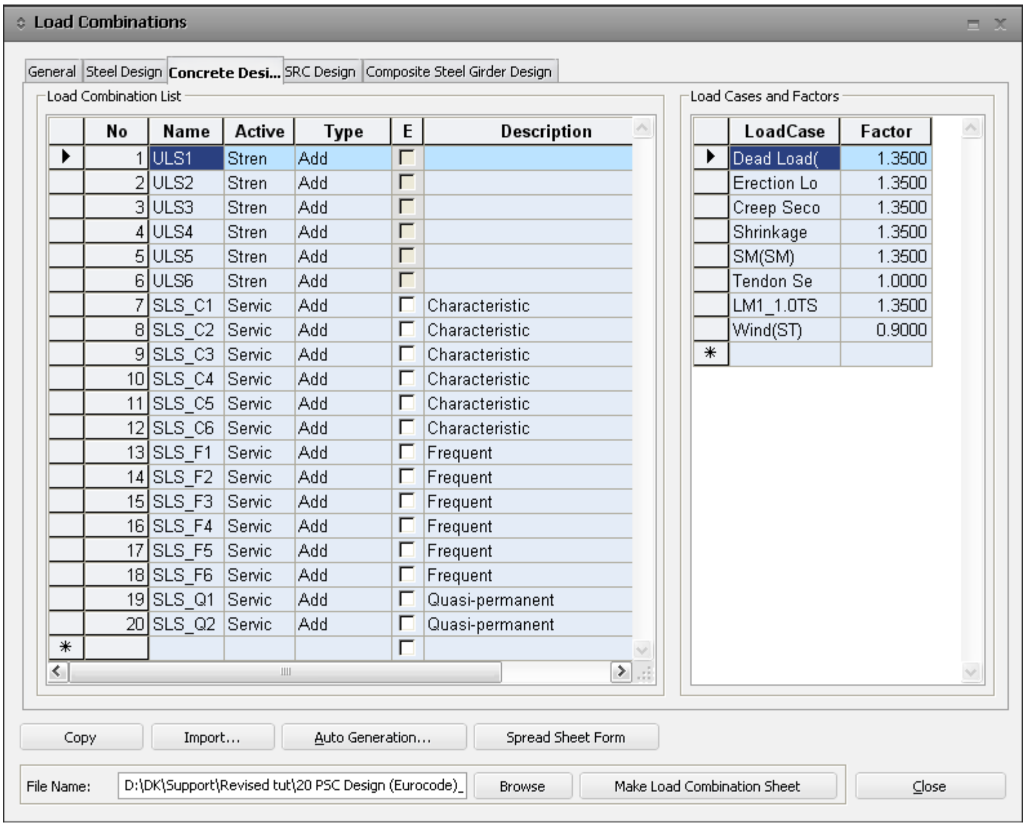


Fig.13 Load combination

PSC Section Design (Procedure & Theory)

STEP 1
Input Design Parameters

PSC > *Parameters…*

Input Parameters

1. Design Code: **EUROCODE2-2: 05**
2. National Annex : **Recommended (on)**
3. Design Parameters (ULS), Moment Resistance: **Consider All Tendons (on)**
4. Shear Resistance, Strut Angle for Shear : **45 (Degree)**

Output Parameters

Select All ↵

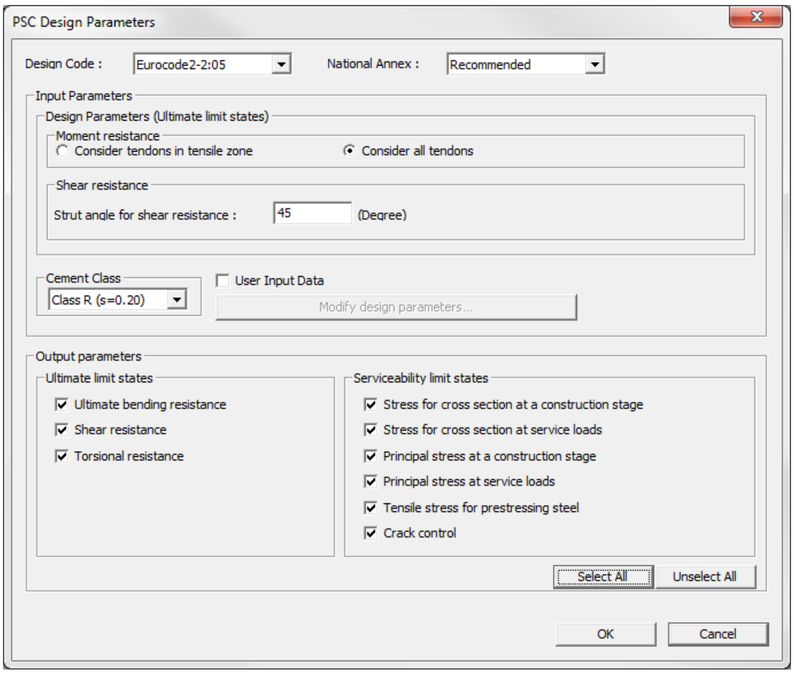


Fig. 14 Defining design parameter

The Following National Annexes are incorporated in the program

a. Recommended
b. British
c. Italy

For Moment of Resistance calculations, the tendons are to be considered only in the Tensile Zone or all the tendons in the cross section. Consideration of all the tendons will increase the resisting Moment and hence will make the design less conservative.
The Strut Angle will be used in the Shear Resistance calculation.
Cement Class is used in calculation of compressive strength of Cement. We have to select one of Class R, Class N, And Class S.

User Input: **Check (on)**
[Click] **Modify design Parameters to be found in National Annex.**
Design Parameters according to the code are default set in the calculations. But the user has the option to edit them.

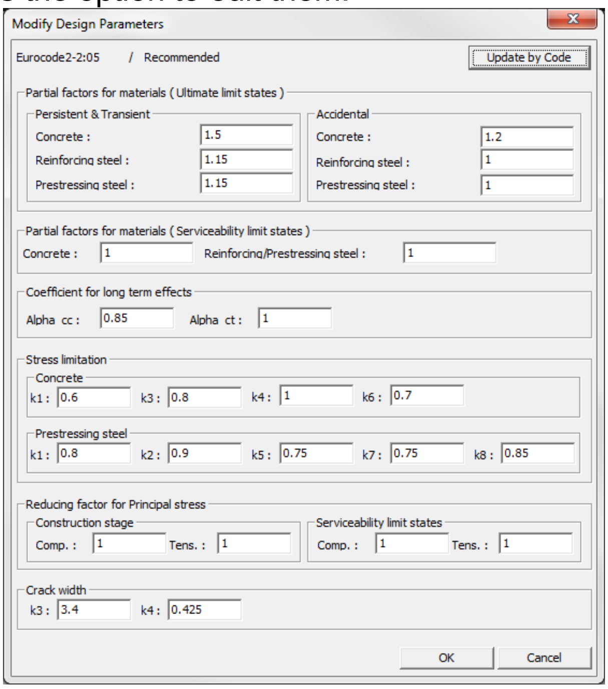


Fig. 15 Defining design parameter

STEP 2
Classify Load Cases

PSC > Short/Long Term Load Case

Long Term
Self-Weight and other permanent loads
Short Term
Wind, Temperature, Moving Loads etc.

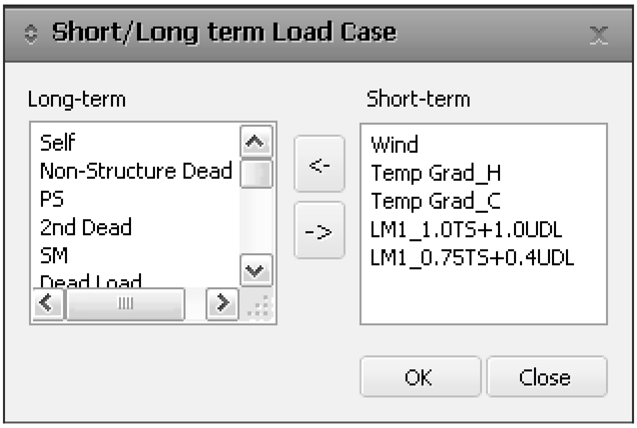


Fig. 16 Short/Long term Load Case

STEP 3

Classify Load Combinations

PSC > Serviceability Load Combination

Classify serviceability load combinations into sub-category, i.e. Characteristic, Frequent, Quasi-permanent.

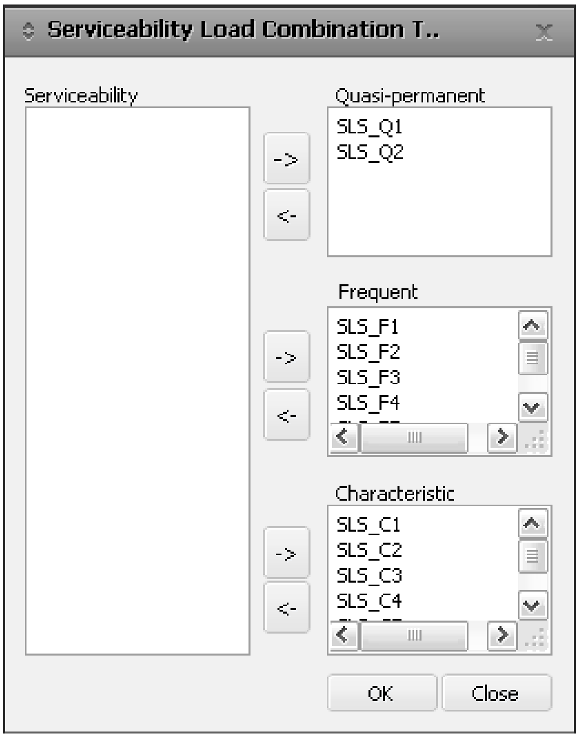


Fig. 17 Serviceability Load Combination Type

STEP 4

Modify material properties

PSC > *PSC Design Material…*
Material List> ID1
Concrete Material Selection
Code> **EN04(RC)**
Grade>**C40/50**
Rebar Selection
Code> **EN04(RC)**
Grade of Main Rebar>Class A
Grade of Sub-Rebar>Class A
Modify ↵

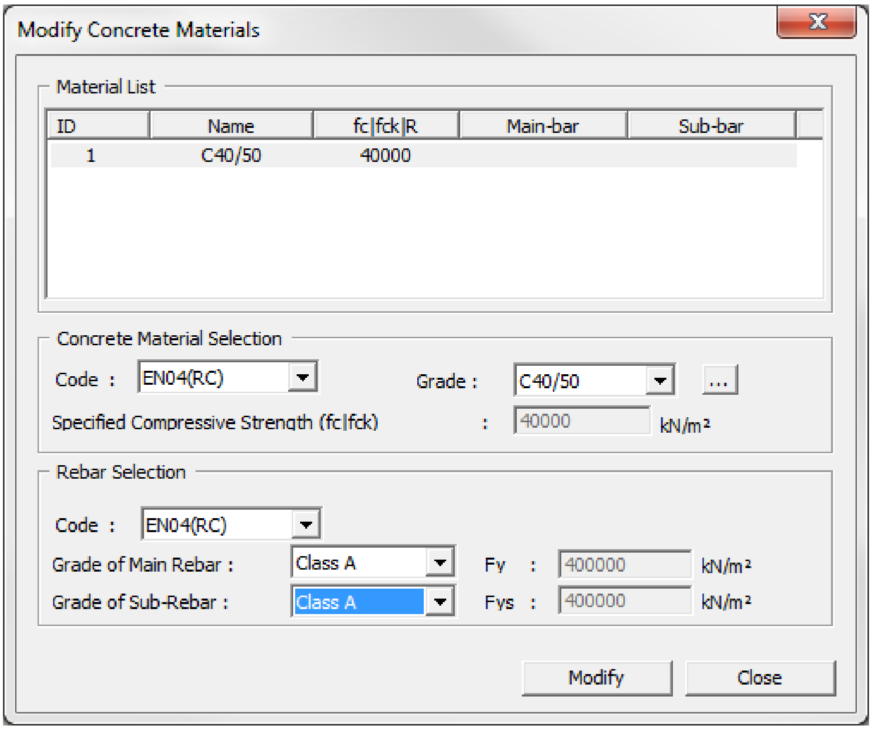


Fig. 18 Modify concrete and rebar materials for design

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. C40/50, we only need to specify the grades of Main rebar i.e. longitudinal steel and sub-rebar i.e. steel used for shear reinforcement.

STEP 5

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 Option…*
Option>Add/Replace
Select All
Moment> **I &J** (on)
Shear> **I &J** (on)

STEP 6

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 Print Option…*
Option : **Add/Replace**
Select Elements by Identifying… (Element: **16, 26**)
Moment Strength> M (+) >**J** (on)
Moment Strength> M (-) >**J** (on)
Shear Strength> **J** (on)
Torsion Strength> **J** (on) ↵
Click **[Apply]**

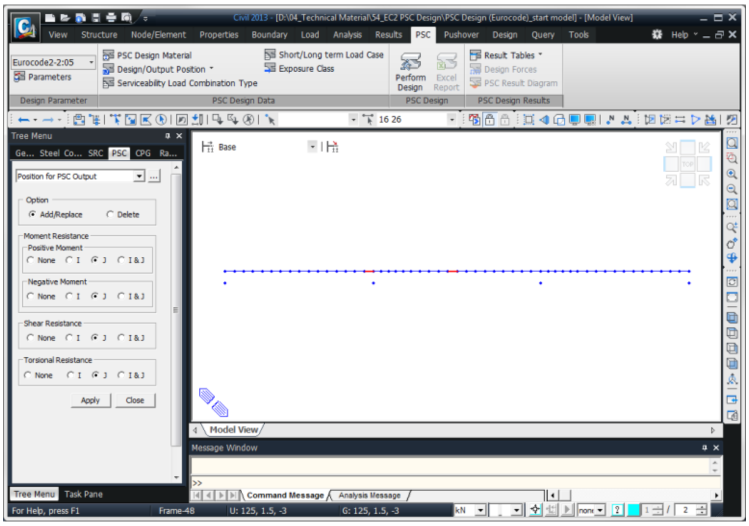


Fig. 19 PSC Print Option dialog box

STEP 7

Exposure Class

This feature enables the user to provide exposure classes specific to each element and at the Top and Bottom surface of a section. Like other functions user can edit in tabular format also. By default if not assigned the Class XC1 is applied at both top and bottom surfaces.

PSC > *Exposure Class*
Option: **Add/Replace**
Select All
Top:**XC1**
Bottom:**XC1**
Click **[Apply]**

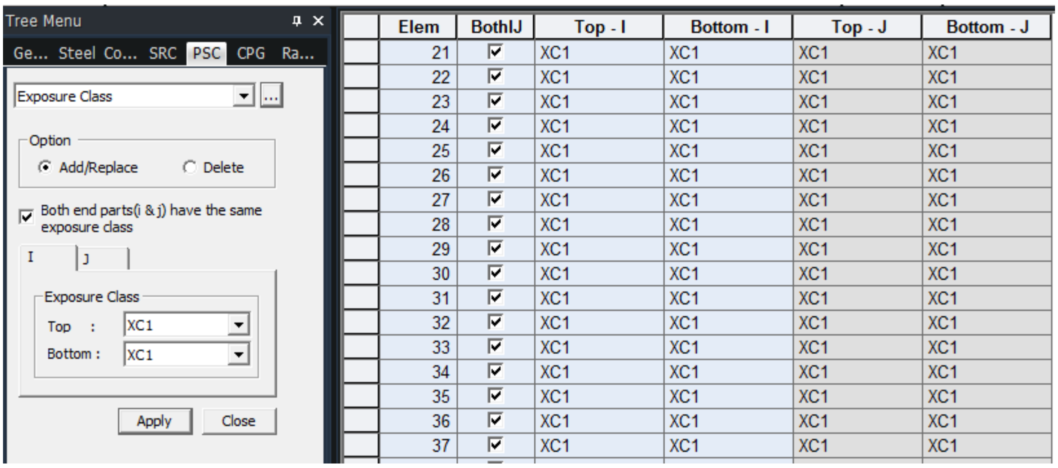


Fig. 20 Exposure Class

STEP 8

Perform the PSC Design

PSC > **Perform *Design*** ↵

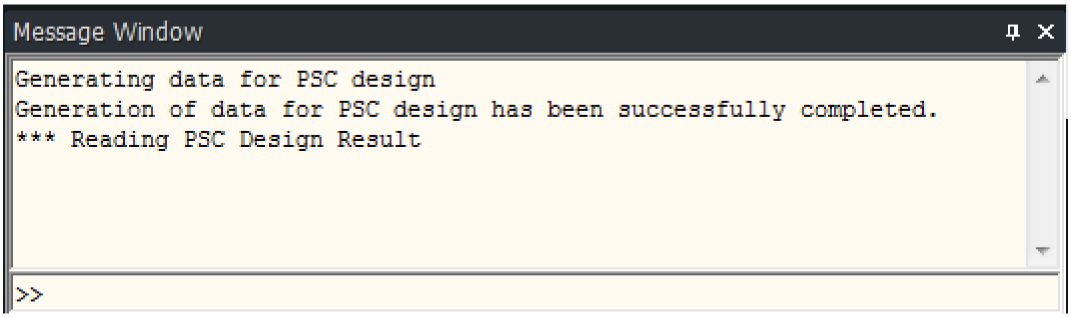


Fig. 21 Message after completing PSC Design

Design Results

We can see the design results in Tables (**Design>PSC Design>PSC Design 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

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 Calculations…*** ↵

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.

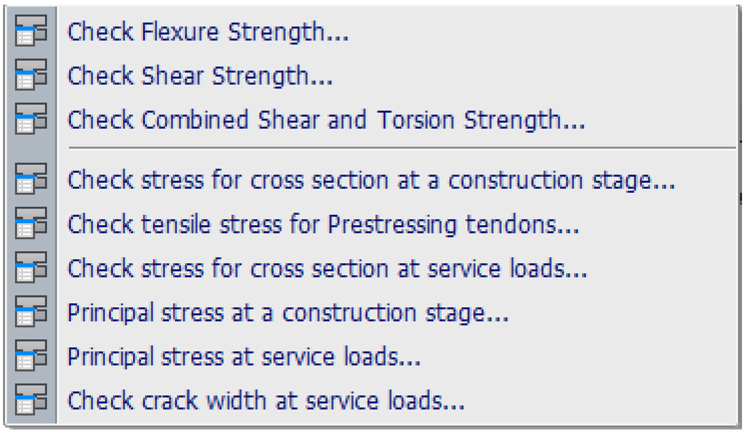


Fig. 22 PSC design result tables

Following sign convention is used for stresses
Compression: (+)
Tension: (-)

Check Flexure Strength

Elem	Part	Positive/ Negative	LCom Name	Design Situations	Type	CHK	M_Ed (kN*m)	M_Rd (kN*m)	M_Ed/M_Rd	Aps (m^2)
21	I[21]	Negative	ULS1	Persistent & T	MY-MIN	OK	-335.5608	36587.3980	0.0092	0.0211
21	I[21]	Positive	ULS3	Persistent & T	MY-MAX	OK	33140.4909	61480.6611	0.5390	0.0211
21	J[22]	Negative	ULS1	Persistent & T	MY-MIN	OK	0.0000	27799.9824	0.0000	0.0211
21	J[22]	Positive	ULS3	Persistent & T	MY-MAX	OK	40962.7886	70397.5263	0.5819	0.0211
22	I[22]	Negative	ULS1	Persistent & T	MY-MIN	OK	0.0000	27799.9824	0.0000	0.0211
22	I[22]	Positive	ULS3	Persistent & T	MY-MAX	OK	40963.2645	70397.5263	0.5819	0.0211
22	J[23]	Negative	ULS1	Persistent & T	MY-MIN	OK	0.0000	21741.9432	0.0000	0.0211
22	J[23]	Positive	ULS3	Persistent & T	MY-MAX	OK	49066.7172	77085.2359	0.6365	0.0211
23	I[23]	Negative	ULS1	Persistent & T	MY-MIN	OK	0.0000	21741.9677	0.0000	0.0211
23	I[23]	Positive	ULS3	Persistent & T	MY-MAX	OK	49064.0545	77085.2359	0.6365	0.0211
23	J[24]	Negative	ULS1	Persistent & T	MY-MIN	OK	0.0000	20344.6891	0.0000	0.0211
23	J[24]	Positive	ULS3	Persistent & T	MY-MAX	OK	55198.9786	78703.5402	0.7014	0.0211
24	I[24]	Negative	ULS1	Persistent & T	MY-MIN	OK	0.0000	20344.6956	0.0000	0.0211
24	I[24]	Positive	ULS3	Persistent & T	MY-MAX	OK	55197.4955	78703.5402	0.7013	0.0211
24	J[25]	Negative	ULS1	Persistent & T	MY-MIN	OK	0.0000	20327.5936	0.0000	0.0211
24	J[25]	Positive	ULS3	Persistent & T	MY-MAX	OK	59340.0060	78715.5089	0.7539	0.0211
25	I[25]	Negative	ULS1	Persistent & T	MY-MIN	OK	0.0000	20327.5931	0.0000	0.0211
25	I[25]	Positive	ULS3	Persistent & T	MY-MAX	OK	59340.1390	78715.5089	0.7539	0.0211
25	J[26]	Negative	ULS1	Persistent & T	MY-MIN	OK	0.0000	20321.0688	0.0000	0.0211
25	J[26]	Positive	ULS2	Persistent & T	MY-MAX	OK	62213.1703	78718.0713	0.7903	0.0211
26	I[26]	Negative	ULS1	Persistent & T	MY-MIN	OK	0.0000	20321.0659	0.0000	0.0211
26	I[26]	Positive	ULS2	Persistent & T	MY-MAX	OK	62213.9338	78718.0713	0.7903	0.0211
26	J[27]	Negative	ULS1	Persistent & T	MY-MIN	OK	0.0000	20314.7214	0.0000	0.0211
26	J[27]	Positive	ULS2	Persistent & T	MY-MAX	OK	63179.2081	78717.4901	0.8026	0.0211

Table Parameters

Elem	Element number	M_{Rd}	Nominal moment
Part	location of check (I-end, J-end)	M_{Ed} / M_{Rd}	moment ratio
Positive/ Negative	positive moment, negative moment	As,min	minimum required reinforcing steel area
LCom Name	Load combination name	Check	OK/NG
Type	produce maximum and minimum member force components for the load combinations including moving load cases		

Calculations

M_{Rd}, Bending resistance

(1) Determine the distance between the temporary neutral axis and the extreme fiber of concrete that is in compression. When the strain of compression extreme fiber is ε_{cu2} or ε_{cu3}, calculate strain ε_s and $\Delta\varepsilon_p$ for reinforced and Prestressing steel.

(2) Calculate F_c (Concrete), F_s (Steel) and F_p (Tendon)

$$F_c = \lambda x \times \eta f_{cd}$$

$$F_s = f_s A_s \quad , \quad f_s = \varepsilon_s E_s$$

$$F_p = f_p A_p \quad , \quad f_p = \varepsilon_p E_p \, ,$$

$$\varepsilon_p = \Delta\varepsilon_p + \varepsilon_{p(0)}$$

Note: For Unbonded Tendons value of $\Delta\varepsilon_p = 100/E_p$

(3) $C = T$

$$F_c - (F_s + F_p) < \Delta$$

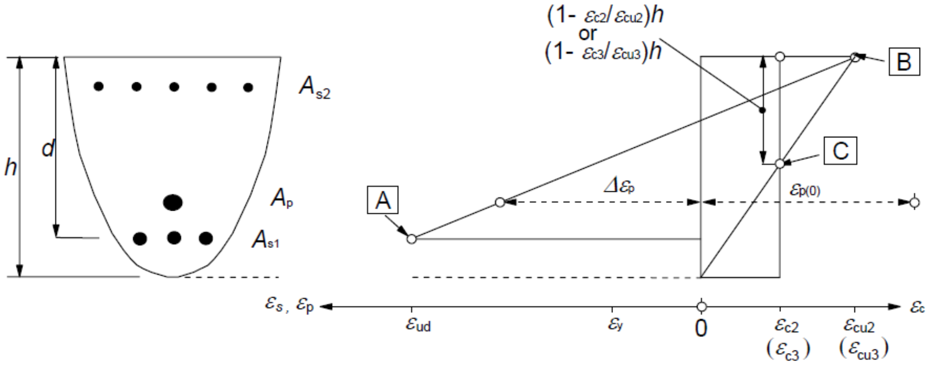
(4) Determine depth of the neutral axis (x)

Repeat 1) ~2) to satisfy (3) (by trial and error)

(5) M_{Rd}, bending resistance

From the determined neutral axis depth, calculate M_{Rd}

$M_{Rd} = F_c a_c + F_s a_s + F_p a_p$ (a = distance from the neutral axis)



$(1- \varepsilon_{c2}/\varepsilon_{cu2})h$
or
$(1- \varepsilon_{c3}/\varepsilon_{cu3})h$
A_{s2}
d
h
A_p
A_{s1}
A
B
C
$\Delta\varepsilon_p$
$\varepsilon_{p(0)}$
ε_s, ε_p
ε_{ud}
ε_y
0
ε_{c2}
(ε_{c3})
ε_{cu2}
(ε_{cu3})
ε_c

Check Shear Strength

Elem	Part	Max/Min	LCom Name	Design Situations	Type	CHK	V_Ed (kN)	V_Rd (kN)	V_Rd,c (kN)	V_Rd,s (kN)	V_Rd,max (kN)	V_Ed/V_Rd
14	J[15]	Max	ULS1	Persistent & T	FZ-MAX	OK	7352.1371	9500.4433	5107.2419	9500.4433	15790.9180	0.7739
14	J[15]	Min	ULS3	Persistent & T	FZ-MIN	OK	4047.9854	5028.2757	5028.2757	9532.7588	15777.7434	0.8050
15	I[15]	Max	ULS1	Persistent & T	FZ-MAX	OK	7352.1502	9500.4433	5028.5214	9500.4433	15724.4635	0.7739
15	I[15]	Min	ULS3	Persistent & T	FZ-MIN	OK	4047.9985	4990.0067	4990.0067	9532.7588	15745.7032	0.8112
15	J[16]	Max	ULS1	Persistent & T	FZ-MAX	OK	8210.3984	9500.4433	5028.8005	9500.4433	15724.6974	0.8642
15	J[16]	Min	ULS3	Persistent & T	FZ-MIN	OK	4735.3554	4990.2454	4990.2454	9532.7588	15745.9023	0.9489
16	I[16]	Max	ULS1	Persistent & T	FZ-MAX	OK	8210.1802	9500.4433	4992.7904	9500.4433	15694.6407	0.8642
16	I[16]	Min	ULS3	Persistent & T	FZ-MIN	OK	4735.1280	4933.5905	4933.5905	9532.7588	15698.9159	0.9598
16	J[17]	Max	ULS1	Persistent & T	FZ-MAX	OK	9364.8062	9500.4433	4992.8865	9500.4433	15694.7206	0.9857
16	J[17]	Min	ULS3	Persistent & T	FX-MIN	OK	5680.3669	9500.4433	1708.6603	9500.4433	15645.7687	0.5979
17	I[17]	Max	ULS1	Persistent & T	FZ-MAX	OK	-5834.7049	9500.4433	4937.2112	9500.4433	15648.6742	0.6142
17	I[17]	Min	ULS2	Persistent & T	FZ-MIN	NG	-9935.9365	9500.4433	4858.6845	9500.4433	15584.6061	1.0458
17	J[18]	Max	ULS1	Persistent & T	FZ-MAX	OK	-5019.4743	9500.4433	4937.2112	9500.4433	15648.6742	0.5283
17	J[18]	Min	ULS2	Persistent & T	FZ-MIN	OK	-8947.8055	9500.4433	4858.6845	9500.4433	15584.6061	0.9418
18	I[18]	Max	ULS1	Persistent & T	FZ-MAX	OK	-5019.5401	9500.4433	4859.6706	9500.4433	15585.4043	0.5283
18	I[18]	Min	ULS2	Persistent & T	FZ-MIN	OK	-8947.8676	9500.4433	4784.4385	9500.4433	15524.9753	0.9418
18	J[19]	Max	ULS1	Persistent & T	FZ-MAX	OK	-4497.3779	4859.6596	4859.6596	9532.7588	15638.4086	0.9255
18	J[19]	Min	ULS2	Persistent & T	FZ-MIN	OK	-8256.6147	9500.4433	4784.2833	9500.4433	15524.8516	0.8691
19	I[19]	Max	ULS1	Persistent & T	FZ-MAX	OK	-4497.4735	5672.6680	5672.6680	9532.7588	16354.0148	0.7928
19	I[19]	Min	ULS2	Persistent & T	FZ-MIN	OK	-8256.6987	9500.4433	5632.9003	9500.4433	16261.1299	0.8691
19	J[20]	Max	ULS1	Persistent & T	FZ-MAX	OK	-3800.3374	5672.6500	5672.6500	9532.7588	16353.9978	0.6699
19	J[20]	Min	ULS2	Persistent & T	FZ-MIN	OK	-7395.7521	9500.4433	5632.6276	9500.4433	16260.8740	0.7785
20	I[20]	Max	ULS1	Persistent & T	FZ-MAX	OK	-3800.3419	5635.8238	5635.8238	9532.7588	16319.1948	0.6743
20	I[20]	Min	ULS2	Persistent & T	FZ-MIN	OK	-7395.7587	9500.4433	5620.7944	9500.4433	16249.7832	0.7785

Table Parameters

Elem	Element number	V_{Ed}	maximum shear force among Strength/Stress load combinations
Part	location of check (I-end, J-end)	V_{Rd}	shear resistance
Max/Min	maximum/minimum shear force	$V_{Rd,c}$	shear resistance of Concrete
LCom Name	Load combination name	$V_{Rd,s}$	shear resistance of shear reinforcement
Type	produce maximum and minimum member force components for the load combinations including moving load cases	$V_{Rd,\max}$	maximum $V_{Rd,s}$
Check	OK/NG	V_{Ed} / V_{Rd}	the ratio of shear force to shear resistance

Calculations

Shear resistance $V_{Rd,c}$

$$V_{Rd,c} = \left[C_{Rd,c} k (100 \rho_1 f_{ck})^{1/3} + k_1 \sigma_{cp}\right] \cdot b_w d$$

With a minimum of

$$V_{Rd,c} = (v_{\min} + k_1 \sigma_{cp}) \cdot b_w d$$

(Where the flexural tensile stress is smaller than $f_{ctk,0.05} / \gamma_c$)

$$V_{Rd,c} = \frac{I b_w}{S} \sqrt{\left(f_{ctd}\right)^2 + \alpha_l \sigma_{cp} f_{ctd}}$$

Shear resistance, $V_{Rd,s}$

For members with vertical shear reinforcement

$$V_{Rd,s} = \frac{A_{sw}}{s} z f_{ywd} \cot \theta$$

$$V_{Rd,\max} = \alpha_{cw} b_w z v_1 f_{cd} / (\cot \theta + \tan \theta)$$

For members with inclined shear reinforcement

$$\frac{A_{sw,\max} f_{ywd}}{b_w s} \le \frac{1}{2} \alpha_{cw} v_1 f_{cd}$$

$$V_{Rd,s} = \frac{A_{sw}}{s} z f_{ywd} (\cot \theta + \cot \alpha) \sin \alpha$$

and

$$V_{Rd,\max} = \alpha_{cw} b_w z v_1 f_{cd} / (\cot \theta + \cot \alpha) / (1 + \cot^2 \theta)$$

$$\frac{A_{sw,\max} f_{ywd}}{b_w s} \leq \frac{\frac{1}{2}\alpha_{cw}\nu_1 f_{cd}}{\sin\alpha}$$

Where α is the Angle of Diagonal reinforcement.
Where the web contains grouted ducts with a diameter $\phi > b_w/8$

$$b_{w,nom} = b_w - 0.5\sum\phi$$

Where ϕ is the outer diameter of the duct and $\sum\phi$ is determined for the most Unfavorable level

For grouted metal ducts with $\phi \leq b_w/8$, $b_{w,nom} = b_w$

For non-grouted ducts, grouted plastic ducts and unbonded tendons

$$b_{w,nom} = b_w - 1.2\sum\phi$$

Check Combined Shear and Torsion Strength

Elem	Part	Max/Min	LCom Name	Design Situations	Type	CHK	T_Ed (kN*m)	T_Rd,max (kN*m)	V_Ed (kN)	V_Rd,max (kN)	Ratio
1	I[1]	T-Max	ULS1	Persistent & T	MX-MIN	OK	-3509.6249	95675.8772	-6496.3461	15985.8749	0.4431
1	I[1]	V-Max	ULS1	Persistent & T	FZ-MAX	OK	-510.6050	95481.7684	-4705.4470	15953.4426	0.3003
1	I[1]	V-Min	ULS2	Persistent & T	FZ-MIN	OK	1699.2746	95675.2437	-7967.4529	15985.7691	0.5162
1	J[2]	T-Max	ULS1	Persistent & T	MX-MIN	OK	-3193.8211	95675.3261	-5169.2195	16040.1581	0.3556
1	J[2]	V-Max	ULS1	Persistent & T	FZ-MAX	OK	-443.4623	95481.7213	-3310.6241	16007.6998	0.2115
1	J[2]	V-Min	ULS2	Persistent & T	FZ-MIN	OK	906.7708	95674.7274	-6313.5976	16040.0577	0.4031
2	I[2]	T-Max	ULS1	Persistent & T	MX-MIN	OK	-3193.8008	95876.2459	-5169.0851	16073.8427	0.3549
2	I[2]	V-Max	ULS1	Persistent & T	FZ-MAX	OK	-443.4418	95663.5412	-3310.6459	16038.1823	0.2111
2	I[2]	V-Min	ULS2	Persistent & T	FZ-MIN	OK	906.7505	95875.6301	-6313.6200	16073.7394	0.4022
2	J[3]	T-Max	ULS1	Persistent & T	MX-MIN	OK	-2912.1355	95875.6821	-4311.1390	16073.7481	0.2986
2	J[3]	V-Max	ULS1	Persistent & T	FZ-MAX	OK	79.4224	95662.8925	-2587.7213	16038.0735	0.1622
2	J[3]	V-Min	ULS2	Persistent & T	FZ-MIN	OK	727.9167	95875.0906	-5416.9946	16073.6490	0.3446
3	I[3]	T-Max	ULS1	Persistent & T	MX-MIN	OK	-2913.4850	96098.0293	-4316.8232	16111.0251	0.2983
3	I[3]	V-Max	ULS1	Persistent & T	FZ-MAX	OK	78.0749	95864.4743	-2587.7077	16071.8691	0.1618
3	I[3]	V-Min	ULS2	Persistent & T	FZ-MIN	OK	729.2651	96098.0293	-5416.9821	16111.0251	0.3438
3	J[4]	T-Max	ULS1	Persistent & T	MX-MIN	OK	-2653.8099	96098.0293	-3464.9540	16111.0251	0.2427
3	J[4]	V-Max	ULS1	Persistent & T	FZ-MAX	OK	182.8699	95864.4743	-1806.8140	16071.8691	0.1143
3	J[4]	V-Min	ULS2	Persistent & T	FZ-MIN	OK	556.6014	96098.0293	-4534.3355	16111.0251	0.2872
4	I[4]	T-Max	ULS1	Persistent & T	MX-MIN	OK	-2653.8099	96298.1284	-3464.9434	16144.5721	0.2422
4	I[4]	V-Max	ULS1	Persistent & T	FZ-MAX	OK	182.8699	96086.2497	-1806.8034	16109.0502	0.1141
4	I[4]	V-Min	ULS2	Persistent & T	FZ-MIN	OK	556.6014	96298.1284	-4534.3249	16144.5721	0.2866
4	J[5]	T-Max	ULS1	Persistent & T	MX-MIN	OK	-2416.1252	96298.1284	-2619.5755	16144.5721	0.1873

Table Parameters

Elem	Element number	T_{Ed}	maximum torsional moment among Strength/Stress load combinations
Part	location of check (I-end, J-end)	$T_{Rd,\max}$	Design torsional resistance moment
Max/Min	Check for three cases, T-Max, V-Max and V-min.	V_{Ed}	maximum shear force among Strength/Stress load combinations
LCom Name	Load combination name	$V_{Rd,s}$	shear resistance of shear reinforcement
Type	Produce maximum and minimum member force components for the load combinations including moving load cases	$V_{Rd,\max}$	maximum $V_{Rd,s}$
Check	OK/NG		

Calculations

$V_{Rd,\max}$: $V_{Rd,\max} = \alpha_{cw} b_w z \nu_1 f_{cd} /(\cot\theta + \cot\alpha)/(1+\cot^2\theta)$

The maximum resistance of a member subjected to torsion and shear

For solid cross-sections:

$T_{Ed}/T_{Rd,\max} + V_{Ed}/V_{Rd,\max} \leq 1.0$

T_{Ed} is the design torsional moment
V_{Ed} is the design transverse force

$T_{Rd,\max}$ is the design torsional resistance moment according to

$T_{Rd,\max} = 2\nu\alpha_{cw} f_{cd} A_k t_{ef,i} \sin\theta\cos\theta$

$t_{ef,i} = A/u$

For box sections

Each wall should be designed separately for combined effects of shear and torsion. The ultimate limit state for concrete should be checked with reference to the design shear resistance.

Check Stress for cross section at a construction Stage

Elem	Part	Comp./Tens.	Stage	CHK	FT (kN/m^2)	FB (kN/m^2)	FTL (kN/m^2)	FBL (kN/m^2)	FTR (kN/m^2)	FBR (kN/m^2)	FMAX (kN/m^2)	ALW (kN/m^2)
1	I[1]	Compression	CS1	OK	1794.8296	6636.0388	1794.8296	6636.0388	1794.8296	6636.0388	6636.0388	24000.0000
1	J[2]	Compression	CS1	OK	2217.4469	6215.7768	2217.4469	6215.7768	2217.4469	6215.7768	6215.7768	24000.0000
2	I[2]	Compression	CS1	OK	2217.4469	6215.7768	2217.4469	6215.7768	2217.4469	6215.7768	6215.7768	24000.0000
2	J[3]	Compression	CS1	OK	2341.1375	6269.9829	2341.1374	6269.9829	2341.1376	6269.9830	6269.9830	24000.0000
3	I[3]	Compression	CS1	OK	2341.1375	6269.9829	2341.1374	6269.9829	2341.1376	6269.9830	6269.9830	24000.0000
3	J[4]	Compression	CS1	OK	2445.5512	6373.7404	2445.5511	6373.7403	2445.5513	6373.7404	6373.7404	24000.0000
4	I[4]	Compression	CS1	OK	2445.5512	6373.7404	2445.5511	6373.7403	2445.5513	6373.7404	6373.7404	24000.0000
4	J[5]	Compression	CS1	OK	2558.4620	6440.2072	2558.4618	6440.2071	2558.4621	6440.2073	6440.2073	24000.0000
5	I[5]	Compression	CS1	OK	2558.4620	6440.2072	2558.4618	6440.2071	2558.4621	6440.2073	6440.2073	24000.0000
5	J[6]	Compression	CS1	OK	2723.5804	6058.9513	2723.5802	6058.9512	2723.5806	6058.9514	6058.9514	24000.0000
6	I[6]	Compression	CS1	OK	2723.5804	6058.9513	2723.5802	6058.9512	2723.5806	6058.9514	6058.9514	24000.0000
6	J[7]	Compression	CS1	OK	2950.1313	5497.0929	2950.1311	5497.0927	2950.1315	5497.0930	5497.0930	24000.0000
7	I[7]	Compression	CS1	OK	2950.1313	5497.0929	2950.1311	5497.0927	2950.1315	5497.0930	5497.0930	24000.0000
7	J[8]	Compression	CS1	OK	3119.4684	5071.0441	3119.4681	5071.0439	3119.4687	5071.0442	5071.0442	24000.0000
8	I[8]	Compression	CS1	OK	3119.4684	5071.0441	3119.4681	5071.0439	3119.4687	5071.0442	5071.0442	24000.0000
8	J[9]	Compression	CS1	OK	3142.6768	4874.4200	3142.6765	4874.4198	3142.6771	4874.4202	4874.4202	24000.0000
9	I[9]	Compression	CS1	OK	3142.6768	4874.4200	3142.6765	4874.4198	3142.6771	4874.4202	4874.4202	24000.0000
9	J[10]	Compression	CS1	OK	3022.5822	4894.9487	3022.5818	4894.9485	3022.5825	4894.9488	4894.9488	24000.0000
10	I[10]	Compression	CS1	OK	3022.5822	4894.9487	3022.5818	4894.9485	3022.5825	4894.9488	4894.9488	24000.0000
10	J[11]	Compression	CS1	OK	2750.1157	5127.0056	2750.1153	5127.0054	2750.1161	5127.0058	5127.0058	24000.0000
11	I[11]	Compression	CS1	OK	2750.1157	5127.0056	2750.1153	5127.0054	2750.1161	5127.0058	5127.0058	24000.0000
11	J[12]	Compression	CS1	OK	2620.4747	4980.6494	2620.4743	4980.6491	2620.4751	4980.6496	4980.6496	24000.0000
12	I[12]	Compression	CS1	OK	2620.4747	4980.6494	2620.4743	4980.6491	2620.4751	4980.6496	4980.6496	24000.0000

Table Parameters

Elem	Element number	FTL	Combined stress at left top
Part	Check location (I-end, J-end)	FBL	Combined stress at left bottom
Comp/Tens	Compression, Tension	FTR	Combined stress at right top
Stage	Construction stage	FBR	Combined stress at right bottom
CHK	Combined stress check for construction stages	FMAX	max/min combined stress
FT	Top fiber stress	ALW	allowable stress
FB	Bottom fiber stress		

Calculations

Calculate allowable stress

The concrete compressive stress in the structure

$\sigma_c \leq 0.6 f_{ck}(t)$

For pretension elements, $k_6 f_{ck}(t)$

Tensile strength

$$f_{ctm}(t) = (\beta_{cc}(t))^{\alpha} \cdot f_{ctm}$$

Check tensile stress for Prestressing Tendons

Tendon	FDL1 (kN/m^2)	FDL2 (kN/m^2)	FLL1 (kN/m^2)	AFDL1 (kN/m^2)	AFDL2 (kN/m^2)	AFLL1 (kN/m^2)
A1L	1094396.6890	1209052.2376	954911.8681	1440000.0000	1360000.0000	1425000.0000
A1R	1094396.6890	1209052.2376	954911.8704	1440000.0000	1360000.0000	1425000.0000
A2L	1102258.1209	1213979.1022	957821.4157	1440000.0000	1360000.0000	1425000.0000
A2R	1102258.1209	1213979.1022	957821.4180	1440000.0000	1360000.0000	1425000.0000
A3L	1109714.6198	1219413.4261	961689.2098	1440000.0000	1360000.0000	1425000.0000
A3R	1109714.6198	1219413.4261	961689.2122	1440000.0000	1360000.0000	1425000.0000
A4L	1118614.0702	1224198.6514	965591.6937	1440000.0000	1360000.0000	1425000.0000
A4R	1118614.0702	1224198.6514	965591.6962	1440000.0000	1360000.0000	1425000.0000
B1L	1051494.3813	1187364.3771	944185.5492	1440000.0000	1360000.0000	1425000.0000
B1R	1051494.3813	1187364.3771	944185.5456	1440000.0000	1360000.0000	1425000.0000
B2L	969323.7490	1149469.2452	921917.3989	1440000.0000	1360000.0000	1425000.0000
B2R	969323.7490	1149469.2452	921917.3955	1440000.0000	1360000.0000	1425000.0000
B3L	1087539.8609	1206773.2824	953448.6410	1440000.0000	1360000.0000	1425000.0000
B3R	1087539.8609	1206773.2824	953448.6370	1440000.0000	1360000.0000	1425000.0000
B4L	1104508.0195	1214758.7081	959358.5474	1440000.0000	1360000.0000	1425000.0000
B4R	1104508.0195	1214758.7081	959358.5436	1440000.0000	1360000.0000	1425000.0000
C1L	1051571.9323	1187442.0506	943841.2587	1440000.0000	1360000.0000	1425000.0000
C1R	1051571.9323	1187442.0506	943841.2607	1440000.0000	1360000.0000	1425000.0000
C2L	969497.2101	1149469.4802	921414.4347	1440000.0000	1360000.0000	1425000.0000
C2R	969497.2101	1149469.4802	921414.4366	1440000.0000	1360000.0000	1425000.0000

Table Parameters

Tendon	Tendon Profile name		
FDL1	Stress in tendon at anchorages	AFDL1	Allowable stress in tendon at anchorages
FDL2	Maximum stress in tendon along the length of the member away from the anchorages immediately after anchor set	AFDL2	Allowable stress in tendon along the length of the member away from the anchorages immediately after anchor set
FLL	maximum stress in tendon after all lossess at the last stage	AFLL	allowable stress after all losses at the last stage

Calculations

Maximum stress applied to the tendon (AFDL1)

$\sigma_{p,\max}$ = min $\{k_1 f_{pk}\ \ ;\ \ k_2 f_{p0,1k}\}$

Prestressing tendons (AFDL2)

$\sigma_p = k_5 f_{pk}$

k_5 The recommended value 0.75

Check Stress for cross section at Service Loads

Elem	Part	Comp./Tens.	LCom Name	Type	CHK	FT (kN/m^2)	FB (kN/m^2)	FTL (kN/m^2)	FBL (kN/m^2)	FTR (kN/m^2)	FBR (kN/m^2)	FMAX (kN/m^2)
1	I[1]	Compression	SLS_C3	MY-MAX	OK	4336.1560	6284.1633	4336.1560	6284.1633	4336.1560	6284.1633	6284.1633
1	J[2]	Compression	SLS_C3	FX-MAX	OK	5544.2578	4660.6582	5544.1808	4660.6174	5544.3348	4660.6989	5544.3348
2	I[2]	Compression	SLS_C3	MY-MAX	OK	5543.1581	4655.4114	5543.1127	4655.3874	5543.2034	4655.4355	5543.2034
2	J[3]	Compression	SLS_C3	MY-MAX	OK	6370.2237	3622.1832	6370.1433	3622.1406	6370.3042	3622.2258	6370.3042
3	I[3]	Compression	SLS_C3	MY-MAX	OK	6369.9043	3616.6183	6369.8882	3616.6098	6369.9204	3616.6269	6369.9204
3	J[4]	Compression	SLS_C3	MY-MAX	OK	7058.0789	2805.3600	7058.0531	2805.3464	7058.1046	2805.3736	7058.1046
4	I[4]	Compression	SLS_C3	MY-MAX	OK	7057.4072	2799.9206	7057.3815	2799.9069	7057.4330	2799.9342	7057.4330
4	J[5]	Compression	SLS_C3	MY-MAX	OK	7629.2329	2139.6292	7629.1964	2139.6099	7629.2693	2139.6485	7629.2693
5	I[5]	Compression	SLS_C3	MY-MAX	OK	7629.5870	2136.1480	7629.5506	2136.1287	7629.6235	2136.1673	7629.6235
5	J[6]	Compression	SLS_C3	MY-MAX	OK	8115.7122	1369.2877	8115.6641	1369.2622	8115.7604	1369.3132	8115.7604
6	I[6]	Compression	SLS_C3	MY-MAX	OK	8117.5655	1368.5464	8117.5173	1368.5209	8117.6136	1368.5719	8117.6136
6	J[7]	Compression	SLS_C3	MY-MAX	OK	8529.0974	645.2501	8529.0365	645.2179	8529.1583	645.2824	8529.1583
7	I[7]	Compression	SLS_C3	MY-MAX	OK	8530.2794	645.5348	8530.2185	645.5026	8530.3403	645.5670	8530.3403
7	J[8]	Compression	SLS_C3	MY-MAX	OK	8780.7403	175.0731	8780.6656	175.0335	8780.8150	175.1126	8780.8150
8	I[8]	Compression	SLS_C3	MY-MAX	OK	8781.9856	175.8932	8781.9109	175.8536	8782.0603	175.9327	8782.0603
8	J[9]	Compression	SLS_C3	MY-MAX	OK	8806.0954	29.4832	8806.0079	29.4369	8806.1829	29.5295	8806.1829
9	I[9]	Compression	SLS_C3	MY-MAX	OK	8807.9839	30.7404	8807.8964	30.6940	8808.0714	30.7867	8808.0714
9	J[10]	Compression	SLS_C3	MY-MAX	OK	8607.9228	200.1872	8607.8197	200.1326	8608.0259	200.2418	8608.0259
10	I[10]	Compression	SLS_C3	MY-MAX	OK	8610.5647	201.8872	8610.4616	201.8326	8610.6678	201.9418	8610.6678
10	J[11]	Compression	SLS_C3	MY-MAX	OK	8179.6634	684.1104	8179.5436	684.0470	8179.7831	684.1738	8179.7831

Table Parameters

Elem	Element number	FTL	combined stress at left top
Part	Check location (I-end, J-end)	FBL	combined stress at left bottom
Comp/Tens	Compression, Tension	FTR	combined stress at right top
LCom Name	load combination name	FBR	combined stress at right bottom
Type	produce maximum and minimum member force components for the load combinations including moving load cases	FMAX	max/min combined stress
FT	top fiber stress	ALW	allowable stress
FB	bottom fibre stress		

Calculations

Calculate allowable stress

Allowable compressive stress

$\sigma_c = k_1 f_{ck}$

Note: k_1 from National Annex. The recommended value is 0.6

Allowable tensile stress

$\sigma_{ct} = f_{ctm}$

Principal Stress at Construction Stage

Elem	Part	Comp./Tens.	Stage	CHK	Sig_P1 (kN/m^2)	Sig_P2 (kN/m^2)	Sig_P3 (kN/m^2)	Sig_P4 (kN/m^2)	Sig_P5 (kN/m^2)	Sig_P6 (kN/m^2)	Sig_P7 (kN/m^2)	Sig_P8 (kN/m^2)
1	I[1]	Tension	CS4	OK	0.0000	0.0000	0.0000	0.0000	-318.5700	-318.5700	-455.3353	-455.3353
1	J[2]	Tension	CS4	OK	0.0000	0.0000	0.0000	0.0000	-73.9203	-73.9203	-125.9642	-125.9642
2	I[2]	Tension	CS4	OK	0.0000	0.0000	0.0000	0.0000	-74.0040	-74.0040	-126.0729	-126.0729
2	J[3]	Tension	CS4	OK	0.0000	0.0000	0.0000	0.0000	-38.6498	-38.6498	-71.8129	-71.8129
3	I[3]	Tension	CS4	OK	0.0000	0.0000	0.0000	0.0000	-38.6852	-38.6852	-71.8668	-71.8668
3	J[4]	Tension	CS4	OK	0.0000	0.0000	0.0000	0.0000	-26.5576	-26.5576	-52.3420	-52.3420
4	I[4]	Tension	CS4	OK	0.0000	0.0000	0.0000	0.0000	-26.5803	-26.5803	-52.3806	-52.3806
4	J[5]	Tension	CS4	OK	0.0000	0.0000	0.0000	0.0000	-18.6389	-18.6389	-38.3972	-38.3972
5	I[5]	Tension	CS4	OK	0.0000	0.0000	0.0000	0.0000	-18.6481	-18.6481	-38.4150	-38.4150
5	J[6]	Tension	CS4	OK	0.0000	0.0000	0.0000	0.0000	-13.7209	-13.7209	-29.8209	-29.8209
6	I[6]	Tension	CS4	OK	0.0000	0.0000	0.0000	0.0000	-13.7169	-13.7169	-29.8131	-29.8131
6	J[7]	Tension	CS2	OK	0.0000	0.0000	0.0000	0.0000	-11.3193	-11.3193	-21.1966	-21.1966
7	I[7]	Tension	CS2	OK	0.0000	0.0000	0.0000	0.0000	-11.3179	-11.3179	-21.1945	-21.1945
7	J[8]	Tension	CS1	OK	0.0000	0.0000	0.0000	0.0000	-1.4456	-1.4456	-2.8034	-2.8034
8	I[8]	Tension	CS1	OK	0.0000	0.0000	0.0000	0.0000	-1.4455	-1.4455	-2.8032	-2.8032
8	J[9]	Tension	CS4	OK	0.0000	0.0000	0.0000	0.0000	-6.8858	-6.8858	-16.2734	-16.2734
9	I[9]	Tension	CS4	OK	0.0000	0.0000	0.0000	0.0000	-6.8816	-6.8816	-16.2635	-16.2635
9	J[10]	Tension	CS4	OK	0.0000	0.0000	0.0000	0.0000	-30.0565	-30.0565	-67.8680	-67.8680
10	I[10]	Tension	CS4	OK	0.0000	0.0000	0.0000	0.0000	-30.0315	-30.0315	-67.8144	-67.8144
10	J[11]	Tension	CS4	OK	0.0000	0.0000	0.0000	0.0000	-74.8054	-74.8054	-154.6056	-154.6055
11	I[11]	Tension	CS4	OK	0.0000	0.0000	0.0000	0.0000	-74.7142	-74.7142	-154.4411	-154.4410
11	J[12]	Tension	CS4	OK	0.0000	0.0000	0.0000	0.0000	-23.7404	-23.7404	-47.0323	-47.0323
12	I[12]	Tension	CS4	OK	0.0000	0.0000	0.0000	0.0000	-23.7163	-23.7163	-46.9915	-46.9915

Table Parameters

Elem	Element number	Sig_P5	principal stress at the top of left web
Part	Check location (I-end, J-end)	Sig_P6	principal stress at the top of right web
Comp/Tens	Compression, tension	Sig_P7	principal stress at the center of left web
Stage	construction stage	Sig_P8	principal stress at the center of right web
CHK	principal stress check at a construction stage	Sig_P9	principal stress at the bottom of left web
Sig_P1	principal stress at the left top of top flange	Sig_P10	principal stress at the bottom of right web
Sig_P2	principal stress at the right top of top flange	Sig_MAX	the maximum principal stress among P1~P10
Sig_P3	principal stress at the right bottom of bottom flange	Sig_AP	allowable principal stress
Sig_P4	principal stress at the left bottom of bottom flange		

Principal stress at service loads

Elem	Part	Comp./Tens.	LCom Name	Type	CHK	Sig_P1 (kN/m^2)	Sig_P2 (kN/m^2)	Sig_P3 (kN/m^2)	Sig_P4 (kN/m^2)	Sig_P5 (kN/m^2)	Sig_P6 (kN/m^2)	Sig_P7 (kN/m^2)
1	I[1]	Tension	SLS_C4	FX-MAX	OK	-831.0679	-831.0679	0.0000	0.0000	-227.7018	-227.7018	-365.7848
1	J[2]	Tension	SLS_C3	FX-MAX	OK	0.0000	0.0000	0.0000	0.0000	-160.5778	-160.5778	-198.9553
2	I[2]	Tension	SLS_C3	FX-MAX	OK	0.0000	0.0000	0.0000	0.0000	-160.7726	-160.7726	-199.0281
2	J[3]	Tension	SLS_C3	FX-MAX	OK	0.0000	0.0000	0.0000	0.0000	-84.2143	-84.2143	-121.5780
3	I[3]	Tension	SLS_C3	FX-MAX	OK	0.0000	0.0000	0.0000	0.0000	-84.2774	-84.2774	-121.6047
3	J[4]	Tension	SLS_C3	FX-MAX	OK	0.0000	0.0000	0.0000	0.0000	-56.8179	-56.8179	-91.9908
4	I[4]	Tension	SLS_C3	FX-MAX	OK	0.0000	0.0000	0.0000	0.0000	-56.8585	-56.8585	-92.0258
4	J[5]	Tension	SLS_C3	FX-MAX	OK	0.0000	0.0000	0.0000	0.0000	-39.8330	-39.8330	-70.3401
5	I[5]	Tension	SLS_C3	FX-MAX	OK	0.0000	0.0000	0.0000	0.0000	-39.8414	-39.8414	-70.3495
5	J[6]	Tension	SLS_C3	FX-MAX	OK	0.0000	0.0000	0.0000	0.0000	-29.6742	-29.6742	-57.3981
6	I[6]	Tension	SLS_C3	FX-MAX	OK	0.0000	0.0000	0.0000	0.0000	-29.6546	-29.6546	-57.3643
6	J[7]	Tension	SLS_C3	FX-MAX	OK	0.0000	0.0000	0.0000	0.0000	-20.1850	-20.1850	-42.6873
7	I[7]	Tension	SLS_C3	FX-MAX	OK	0.0000	0.0000	0.0000	0.0000	-20.1754	-20.1754	-42.6675
7	J[8]	Tension	SLS_C3	FX-MAX	OK	0.0000	0.0000	0.0000	0.0000	-1.4805	-1.4805	-3.3393
8	I[8]	Tension	SLS_C3	FX-MAX	OK	0.0000	0.0000	0.0000	0.0000	-1.4799	-1.4799	-3.3381
8	J[9]	Tension	SLS_C6	FX-MAX	OK	-0.0000	-0.0000	-0.0000	-0.0000	-7.3090	-6.5084	-17.3187
9	I[9]	Tension	SLS_C6	FX-MAX	OK	-0.0000	-0.0000	-0.0000	-0.0000	-7.3043	-6.5047	-17.3076
9	J[10]	Tension	SLS_C6	FX-MAX	OK	-0.0091	-0.0078	-0.0195	-0.0217	-32.7378	-27.6469	-73.6447
10	I[10]	Tension	SLS_C6	FX-MAX	OK	-0.0091	-0.0078	-0.0194	-0.0217	-32.7093	-27.6249	-73.5838
10	J[11]	Tension	SLS_C6	FX-MAX	OK	-0.0411	-0.0360	-0.0655	-0.0701	-81.4144	-68.7600	-166.7587
11	I[11]	Tension	SLS_C6	FX-MAX	OK	-0.0411	-0.0359	-0.0654	-0.0701	-81.3114	-68.6792	-166.5760
11	J[12]	Tension	SLS_C6	FX-MAX	OK	-0.1043	-0.0952	-0.1356	-0.1407	-27.5447	-20.3113	-53.8197
12	I[12]	Tension	SLS_C6	FX-MAX	OK	-0.1032	-0.0942	-0.1342	-0.1392	-27.5004	-20.3045	-53.7440

Table Parameters

Elem	Element number	Sig_P4	principal stress at the left bottom of bottom flange
Part	Check location (I-end, J-end)	Sig_P5	principal stress at the top of left web
Comp/Tens	Compression, tension	Sig_P6	principal stress at the top of right web
LCom Name	Load combination names of maximum and minimum cases	Sig_P7	principal stress at the center of left web
Type	produce maximum and minimum member force components for the load combinations including moving load cases	Sig_P8	principal stress at the center of right web
CHK	principal stress check at service loads	Sig_P9	principal stress at the bottom of left web
Sig_P1	principal stress at the left top of top flange	Sig_P10	principal stress at the bottom of right web
Sig_P2	principal stress at the right top of top flange	Sig_MAX	the maximum principal stress among P1~P10
Sig_P3	principal stress at the right bottom of bottom flange	Sig_AP	allowable principal stress

Check Crack width at service Loads

	Elem	Part	Top/Bottom	LCom Name	Serviceability Load Type	Type	CHK	N_Ed (kN)	M_Ed (kN*m)	S_r,max (m)	Ep_sm-Ep_cm	Wk (m)	Wmax (m)
	16	J[17]	Bottom	SLS_F1	Frequent	FX-MAX	OK	-13462.5322	-16685.8117	0.0000	0.0000	0.0000	0.0002
	16	J[17]	Top	SLS_F2	Frequent	MY-MIN	NG	-13462.6627	-21897.3423	598.2502	0.0015	0.0009	0.0002
	17	I[17]	Bottom	SLS_F1	Frequent	FX-MAX	OK	-13488.3853	-3657.0886	0.0000	0.0000	0.0000	0.0002
	17	I[17]	Top	SLS_F2	Frequent	MY-MIN	NG	-13488.3853	-21894.6593	598.2502	0.0015	0.0009	0.0002
	17	J[18]	Bottom	SLS_F2	Frequent	MY-MAX	NG	-12757.3084	5389.5120	492.1817	0.0006	0.0003	0.0002
	17	J[18]	Top	SLS_F2	Frequent	MY-MIN	NG	-12757.3084	-12839.6900	598.2502	0.0009	0.0005	0.0002
	18	I[18]	Bottom	SLS_F2	Frequent	MY-MAX	NG	-12763.2547	5392.7847	492.1817	0.0006	0.0003	0.0002
	18	I[18]	Top	SLS_F2	Frequent	MY-MIN	NG	-12761.7688	-12836.4173	598.2502	0.0009	0.0005	0.0002
	18	J[19]	Bottom	SLS_F1	Frequent	MY-MAX	NG	-12077.6176	13580.3108	492.1817	0.0015	0.0007	0.0002
	18	J[19]	Top	SLS_F2	Frequent	MY-MIN	NG	-12077.3042	-6872.0906	598.2502	0.0005	0.0003	0.0002
	19	I[19]	Bottom	SLS_F1	Frequent	FX-MAX	OK	-20952.4174	-7738.4267	0.0000	0.0000	0.0000	0.0002
	19	I[19]	Top	SLS_F1	Frequent	FX-MAX	OK	-20952.4174	-7738.4267	0.0000	0.0000	0.0000	0.0002
	19	J[20]	Bottom	SLS_F1	Frequent	FX-MAX	OK	-20534.7161	-5094.3486	0.0000	0.0000	0.0000	0.0002
	19	J[20]	Top	SLS_F1	Frequent	FX-MAX	OK	-20534.7161	-5094.3486	0.0000	0.0000	0.0000	0.0002
	20	I[20]	Bottom	SLS_F1	Frequent	FX-MAX	OK	-20550.1440	-5730.9366	0.0000	0.0000	0.0000	0.0002
	20	I[20]	Top	SLS_F1	Frequent	FX-MAX	OK	-20550.1440	-5730.9366	0.0000	0.0000	0.0000	0.0002
	20	J[21]	Bottom	SLS_F1	Frequent	FX-MAX	OK	-20399.3506	-4620.2305	0.0000	0.0000	0.0000	0.0002
	20	J[21]	Top	SLS_F1	Frequent	FX-MAX	OK	-20399.3506	-4620.2305	0.0000	0.0000	0.0000	0.0002
	21	I[21]	Bottom	SLS_F1	Frequent	FX-MAX	OK	-16436.7904	-816.6554	0.0000	0.0000	0.0000	0.0002
	21	I[21]	Top	SLS_F1	Frequent	FX-MAX	OK	-16436.7904	-816.6554	0.0000	0.0000	0.0000	0.0002
	21	J[22]	Bottom	SLS_F1	Frequent	FX-MAX	OK	-16967.3068	867.1413	0.0000	0.0000	0.0000	0.0002
	21	J[22]	Top	SLS_F1	Frequent	FX-MAX	OK	-16967.3068	867.1413	0.0000	0.0000	0.0000	0.0002

Table Parameters

Elem	Element number	Type	produce maximum and minimum member force components for the load combinations including moving load cases
Part	Check location (I-end, J-end)	Check	OK/NG
Top/Bottom	top fiber, bottom fiber	w_k	crack
LCom Name	load combination name	w_{max}	allowable crack
Serviceability Load Type	Frequent/ Quassi-Static		

Calculations

$$w_k = s_{r,\max}(\varepsilon_{sm} - \varepsilon_{cm})$$

$$\varepsilon_{sm} - \varepsilon_{cm} = \frac{\sigma_s - k_t \dfrac{f_{ct,eff}}{\rho_{p,eff}}(1 + \alpha_e \rho_{p,eff})}{E_s} \geq 0.6\frac{\sigma_s}{E_s}$$

$$s_{r,\max} = k_3 c + k_1 k_2 k_4 \phi / \rho_{p,eff}$$

ϕ is the bar diameter.

$$\phi = \frac{n_1\phi_1^2 + n_2\phi_2^2}{n_1\phi_1 + n_2\phi_2}$$

If, spacing $> 5(c + \phi/2)$,

$$s_{r,\max} = 1.3(h - x)$$

Check crack

$w_k < w_{\max}$

$w_{\max}$ = Table 7.101N-Recommended value of $w_{\max}$ and relevant combination rules

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.

Design>PSC Design>*PSC Design Forces…*↵

Elem	Part	LCom Name	Type	Fx (kN)	Fy (kN)	Fz (kN)	Mx (kN*m)	My (kN*m)	Mz (kN*m)
1	I	ULS1	FX-MAX	2044.3082	266.5757	-7862.4771	652.7570	-259.4353	0.7412
1	I	ULS1	FX-MIN	2040.7232	266.6424	-4705.4470	-510.6050	-259.4353	-0.5582
1	I	ULS1	FY-MAX	2042.7388	266.8806	-6491.7938	-2657.7473	-259.4353	-2.9315
1	I	ULS1	FY-MIN	2041.9932	266.4045	-5852.0940	1636.2384	-259.4353	1.8151
1	I	ULS1	FZ-MAX	2040.7232	266.6424	-4705.4470	-510.6050	-259.4353	-0.5582
1	I	ULS1	FZ-MIN	2043.2339	266.5795	-7967.4529	678.0696	-259.4353	0.4117
1	I	ULS1	MX-MAX	2042.5819	266.4976	-6972.7349	2488.4199	-259.4353	1.7314
1	I	ULS1	MX-MIN	2042.0262	266.7877	-6496.3461	-3509.6249	-259.4353	-2.8479
1	I	ULS1	MY-MAX	2040.7232	266.6424	-4705.4470	-510.6000	-259.4353	-0.5582
1	I	ULS1	MY-MIN	2043.7742	266.5629	-7404.6099	538.8509	-259.4353	0.6083
1	I	ULS1	MZ-MAX	2042.6704	266.4861	-6702.9955	2007.4819	-259.4353	2.7199
1	I	ULS1	MZ-MIN	2043.2120	266.7992	-7167.3360	-3028.6869	-259.4353	-3.8364
1	I	ULS2	FX-MAX	2044.3082	-266.7101	-7862.4771	1673.9620	-259.4353	1.8576
1	I	ULS2	FX-MIN	2040.7232	-266.6434	-4705.4470	510.6000	-259.4353	0.5582
1	I	ULS2	FY-MAX	2042.7388	-266.4052	-6491.7938	-1636.5422	-259.4353	-1.8150
1	I	ULS2	FY-MIN	2041.9932	-266.8812	-5852.0940	2657.4434	-259.4353	2.9315
1	I	ULS2	FZ-MAX	2040.7232	-266.6434	-4705.4470	510.6000	-259.4353	0.5582
1	I	ULS2	FZ-MIN	2043.2339	-266.7063	-7967.4529	1699.2746	-259.4353	1.5281
1	I	ULS2	MX-MAX	2042.5819	-266.7882	-6972.7349	3509.6249	-259.4353	2.8479

Table Parameters

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 Result Diagram…*** ↵

Load Cases/Combinations> **All COMBINATION**

Option>**Force**

Components> **Flexure-y**

Max, Min

Diagram Option

Scale Factor > **2**

Fill Type > **Solid** ↵

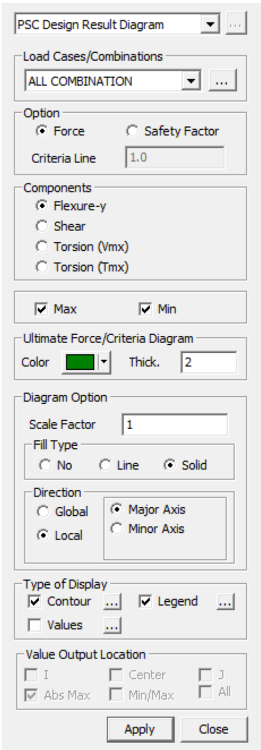


Fig. 23 PSC Design Result Diagram Dialog

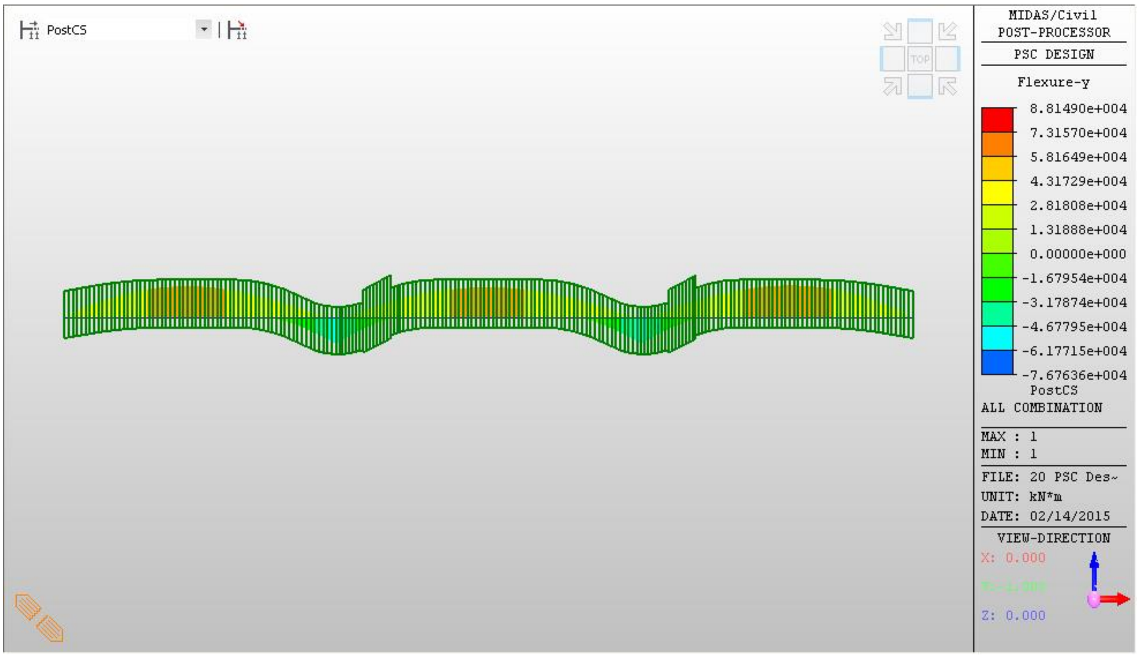


Fig. 24 PSC Design Result Diagram

Excel Report

MS Excel format report is generated for the engineer's verification.

PSC > ***Excel Report …↵***