Release Note

Release Date : December 2020

Product Ver. : Civil 2021 (v1.1)

DESIGN OF CIVIL STRUCTURES

Integrated Solution System for Bridge and Civil Engineering

Enhancements

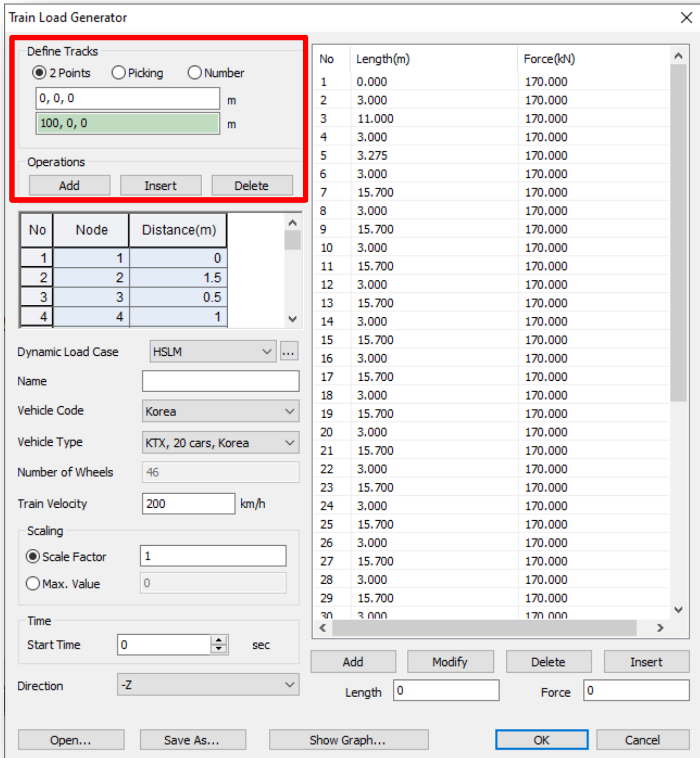
1. Automatic Generation of Moving Train Loads for Dynamic Analysis
2. Debonded Length of Pretensioned Beam
3. Correction of Tendon Force/Stress within Transfer Length of Pretensioned Beams
4. Moving Load Analysis including Centrifugal Force Effects to AASHTO LRFD
5. Update to CS 454 revision 1 for the UK Bridge Assessment
6. Application of Combined Special Vehicle and ALL model 1 for CS 454 Assessment
7. Separate the Results of Combined Vehicles for CS 454 Assessment
8. Pretensioned Beam Design at Transfer to AS 5100.5
9. Transmission Zone Design of Pretensioned Beam to AS 5100.5
10. Crack control for the Slab of PSC Composite Girder to AS 5100.5
11. Joint Check of Segmental Construction to BS 5400.4
12. Response Spectrum Function : IRC SP 114:2018
13. Auto Temperature Gradient as per IRC 6:2017
14. Improvement in Auto Load combinations as per IRC 6:2017
15. Update in General Section Designer as per IRS Specifications

1. Automatic Generation of Moving Train Loads for Dynamic Analysis

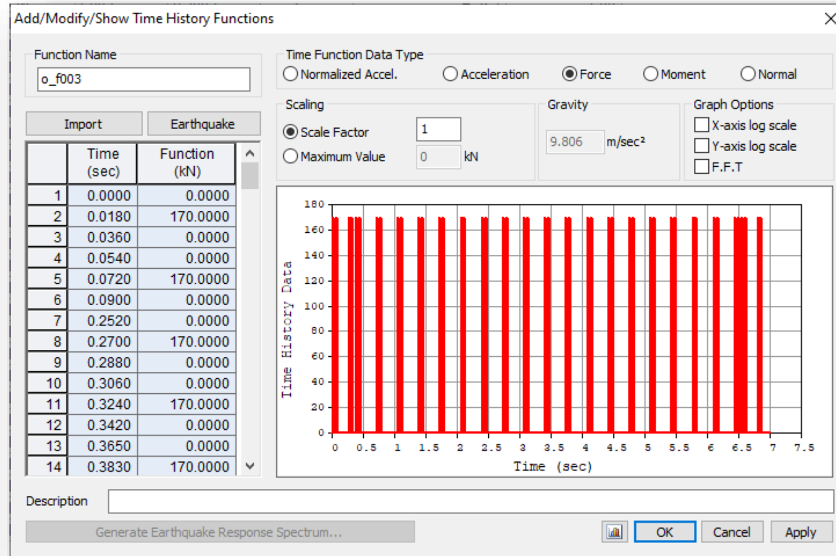
- Generate time-forcing functions without considering the lengths of the element along the track. The required nodal spacing along the track is automatically detected by the program.
- Auto-generate time-forcing function and dynamic nodal loads representing moving train loads. Previously, dynamic nodal loads had to be defined by the user manually.
- This function replaces Tools>Generator>Data Generator>Train Load Generator.

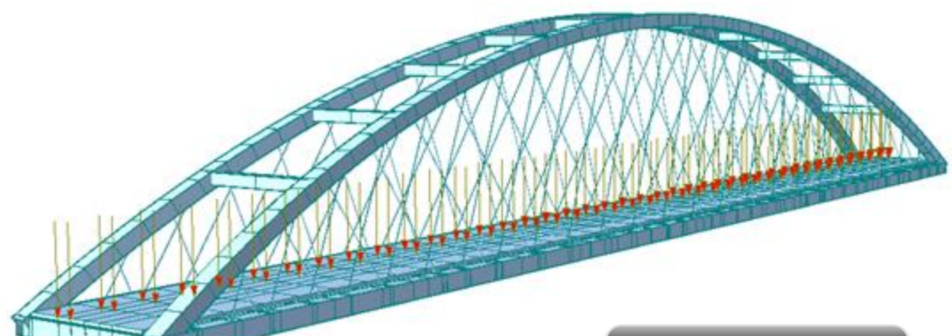
- ***Load > Dynamic Loads > Time History Analysis Data > Train Load Generator***

Define Tracks



Train Load Generator



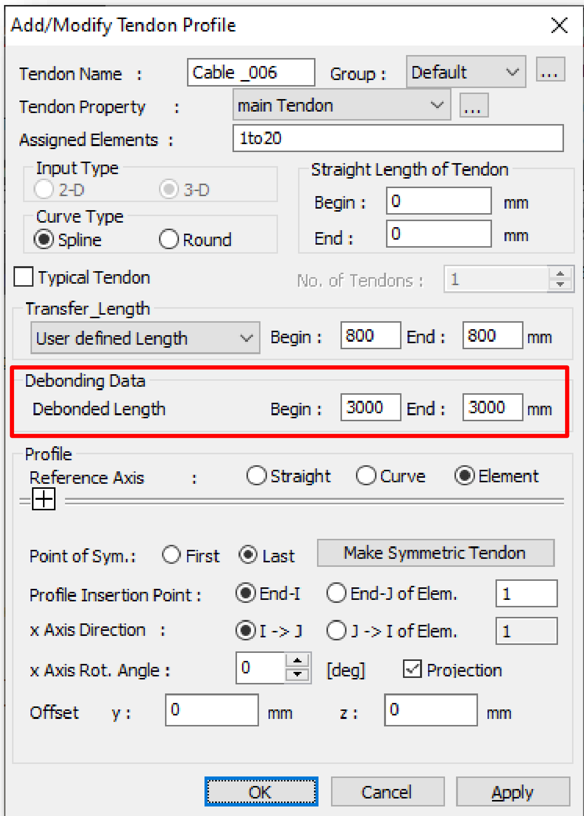


Dynamic Nodal Loads

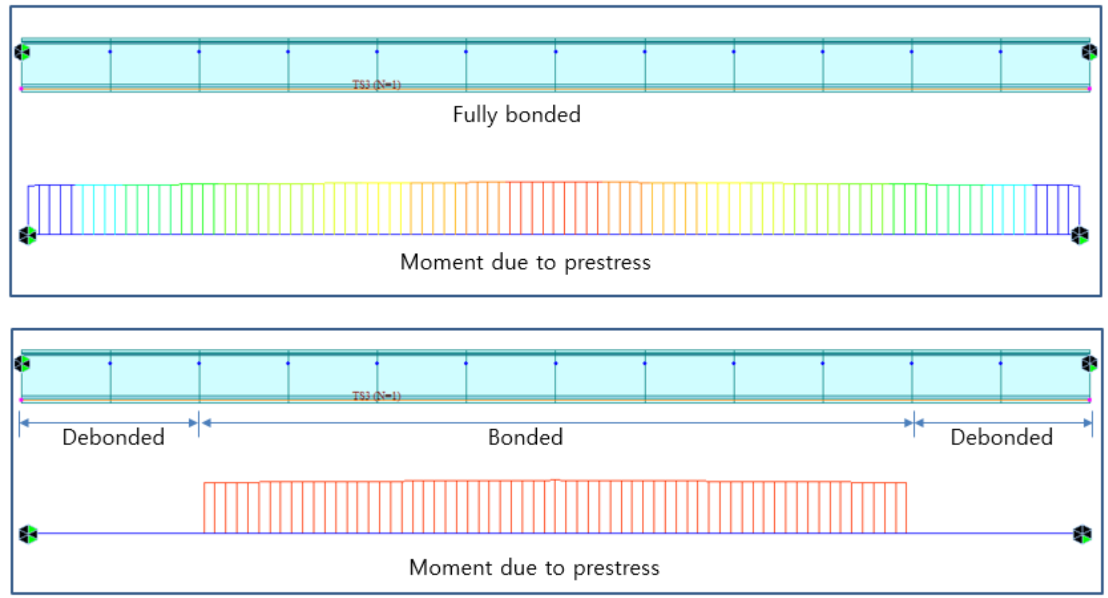
2. Debonded Length of Pretensioned Beam

- Debonded length of pretensioned beam can be directly defined when creating strands from the Tendon Profile dialog box.
- Define the actual whole length of stand including debonded parts at both ends and then enter the lengths for debonded parts.

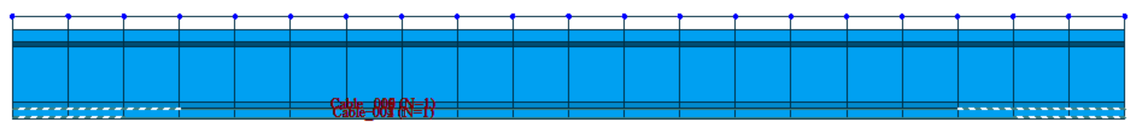
▪ ***Load > Temp./Prestress> Prestress Loads> Tendon Profile***



Tendon Profile



Tendon Primary Moment Diagram

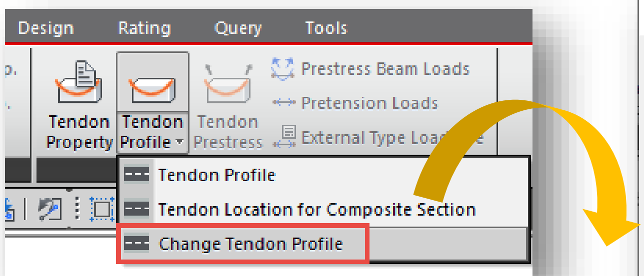


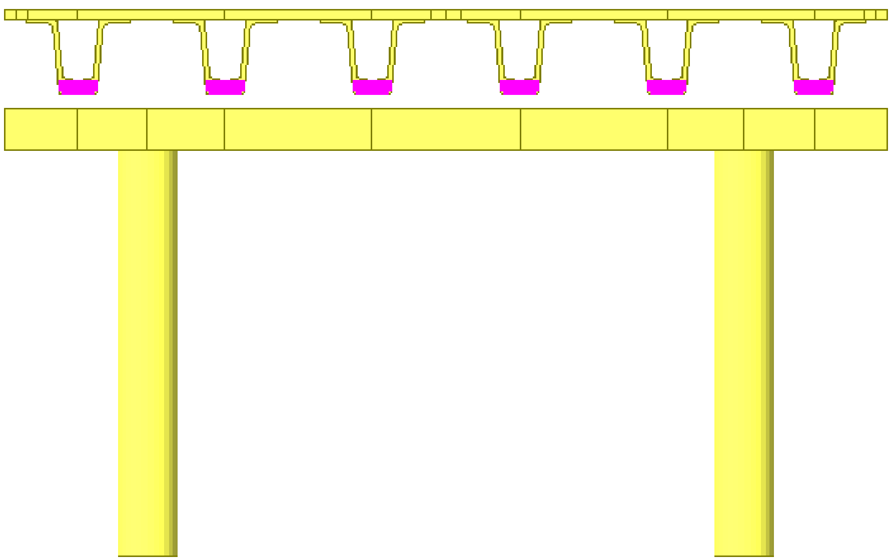
Display of debonded strands

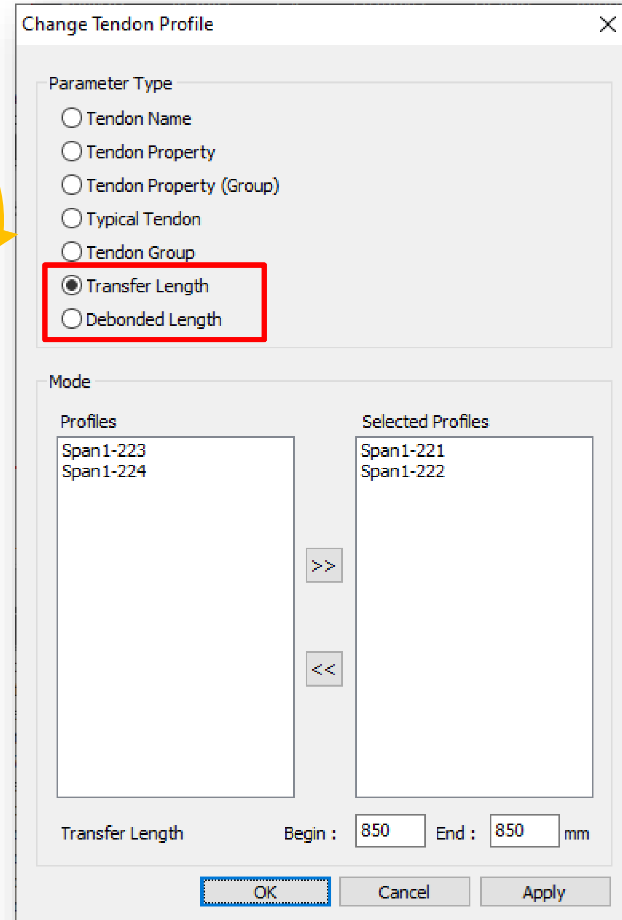
2. Debonded Length of Pretensioned Beam

- Debonded length and transfer length can be modified for the multiple strands at one time.

- ***Load > Temp./Prestress > Prestress Loads > Tendon Profile > Change Tendon Profile***







Change Tendon Profile

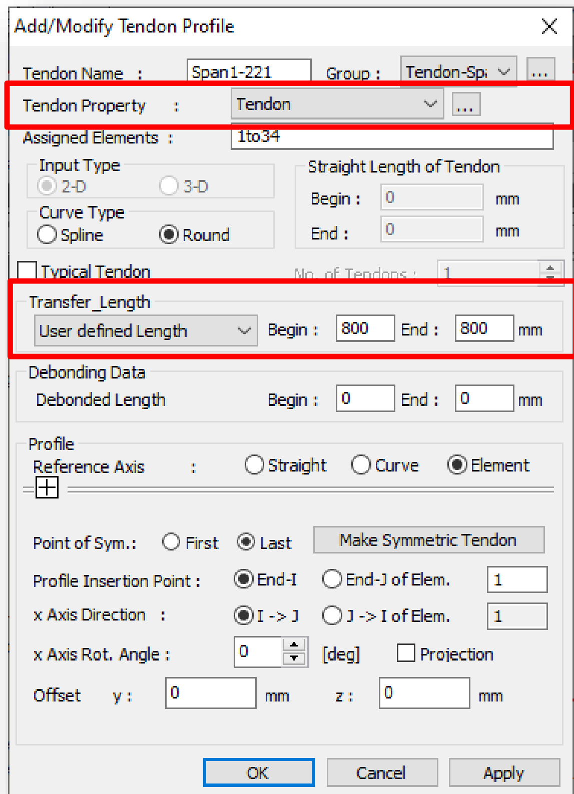
3. Correction of Tendon Force/Stress within Transfer Length of Pretensioned Beams

- The stress in the prestressing steel is assumed to vary linearly from 0.0 at the point where bonding commences, to the effective stress after losses at the end of the transfer length.

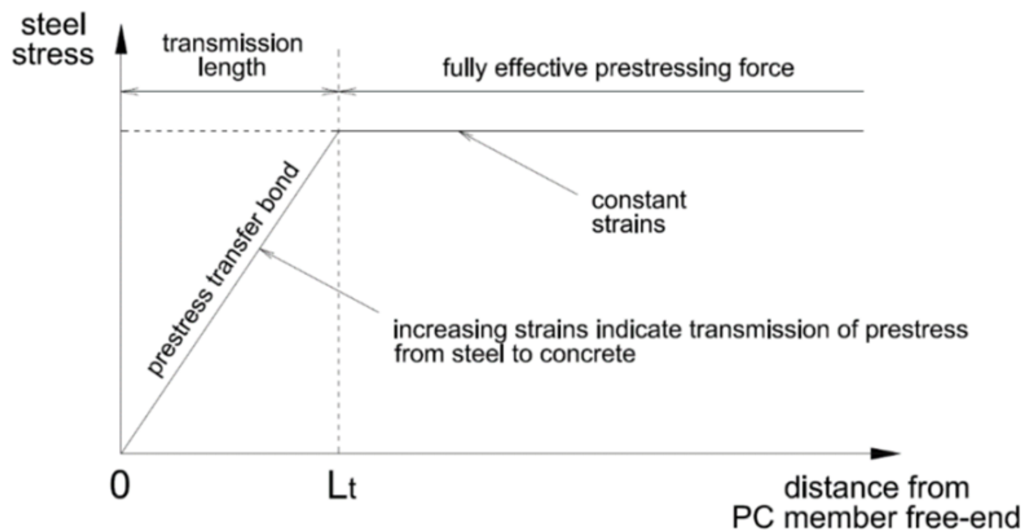
- ***Load* > *Temp./Prestress* > *Tendon Profile***

Pre-tension type

Transfer Length



Tendon Profile

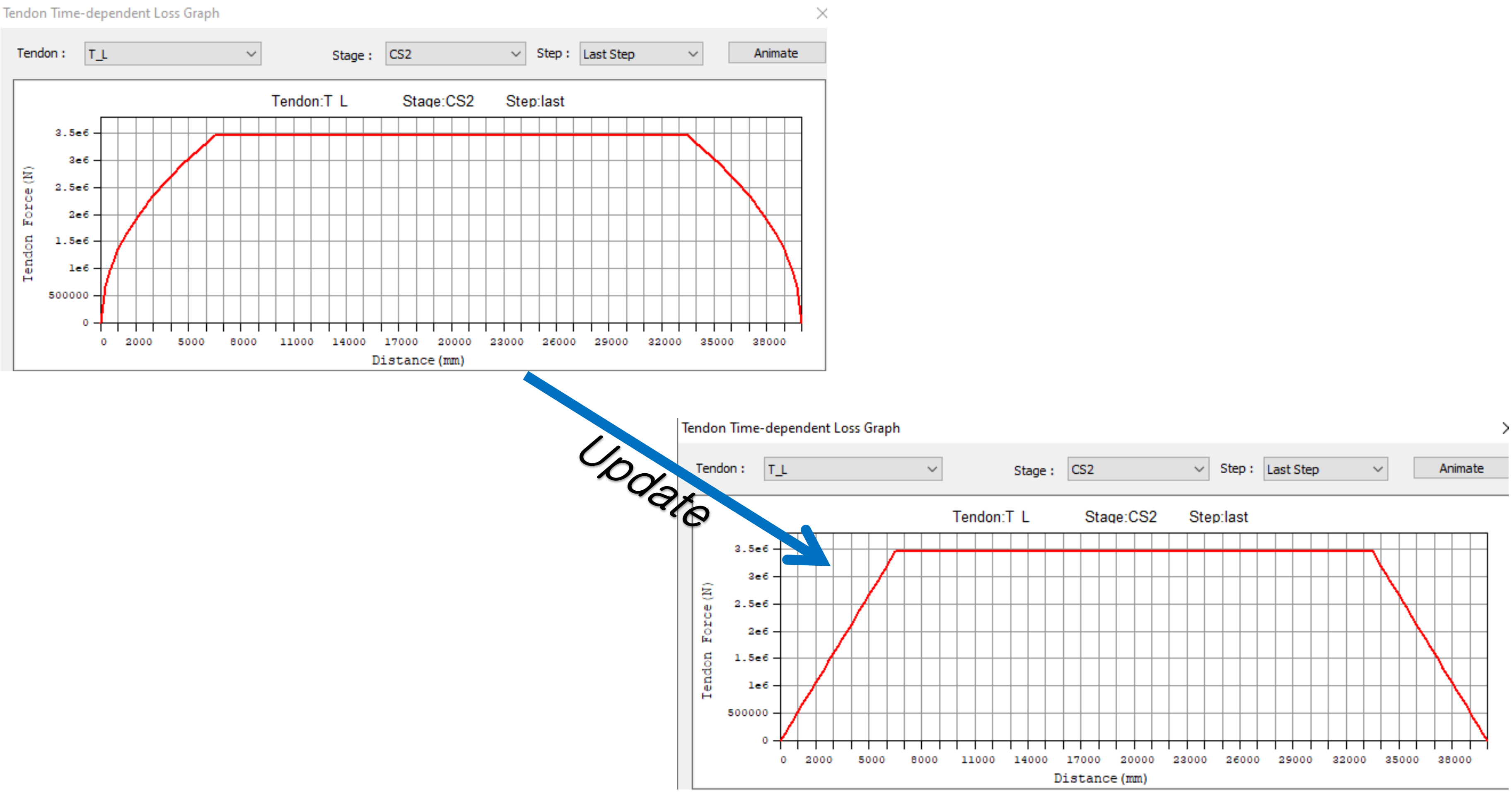


Idealized steel-stress development in PSC member

3. Correction of Tendon Force/Stress within Transfer Length of Pretensioned Beams

- Tendon stresses after immediate loss are determined linearly with the transfer length, and then losses due to creep, shrinkage and relaxation will be calculated along the time.

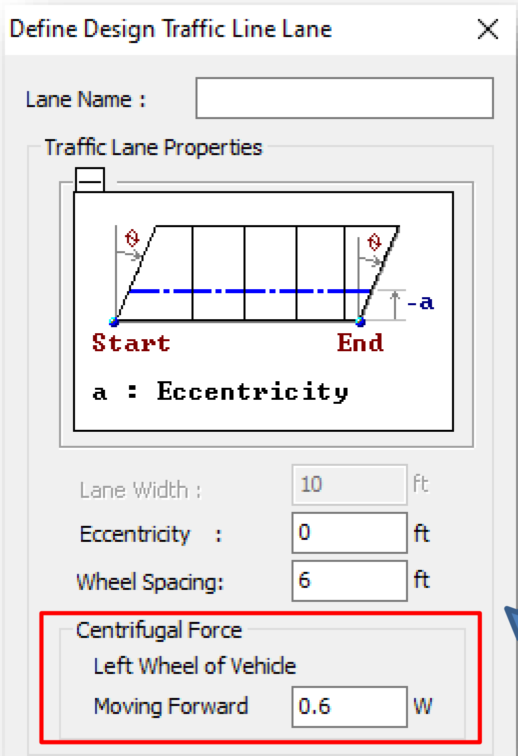
▪ ***Result > Bridge > Tendon Loss Graph***



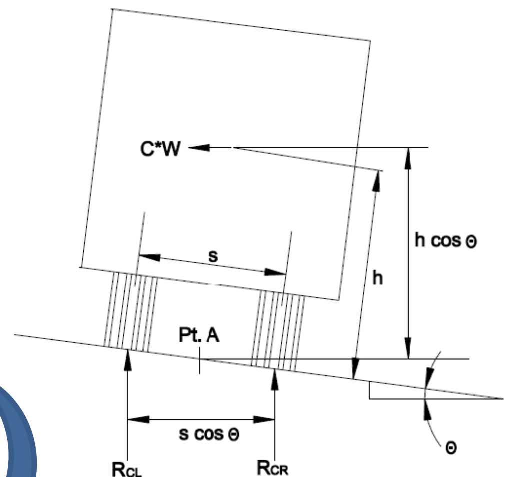
4. Moving Load Analysis including Centrifugal Force Effects to AASHTO LRFD

- The overturning component of centrifugal force is now taken into account during the moving load analysis. The results of vehicle application will be the combination of vertical effect and overturning effect of the vehicle. The overturning component causes the exterior wheel line to apply more than half the weight of the truck and the interior wheel line to apply less than half the weight of the truck by the same amount.
- In order to apply centrifugal forces, the 'Add Centrifugal Force' option should be checked on from the Vehicle definition as well as Traffic Line/Surface Lane.

- ***Load > Moving Load Code> AASHTO LRFD***

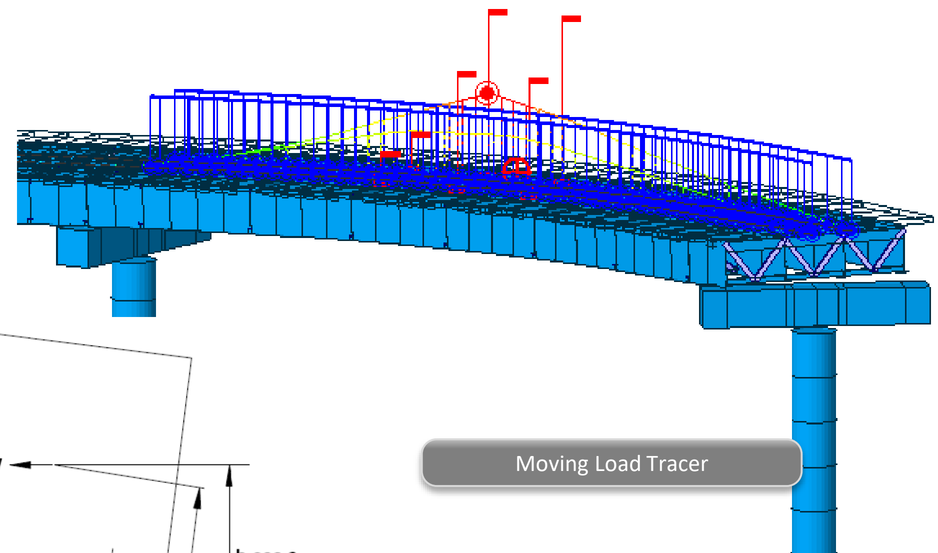


Traffic Line Lane

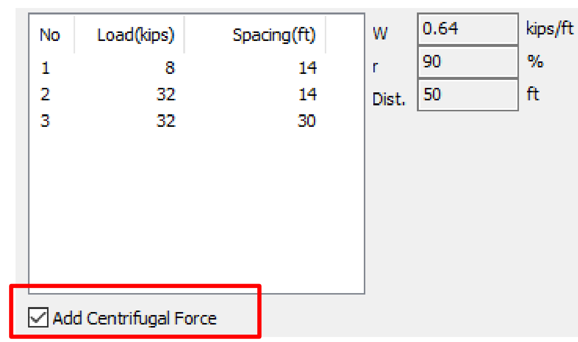


$R_{CL} = 0.6W$ $R_{CR} = 0.4W$

Vehicular Centrifugal Force Wheel-Load Reactions



Moving Load Tracer

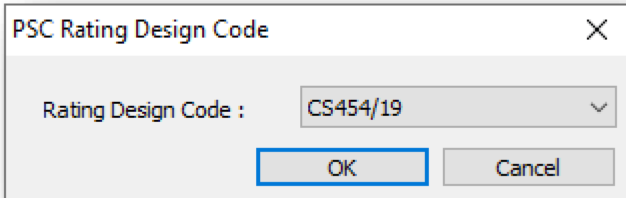


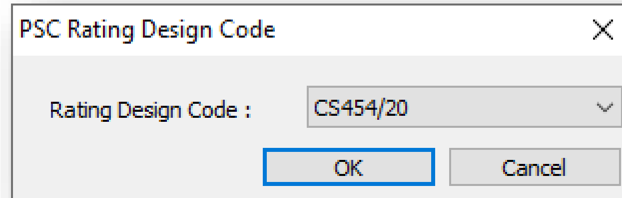
Vehicle

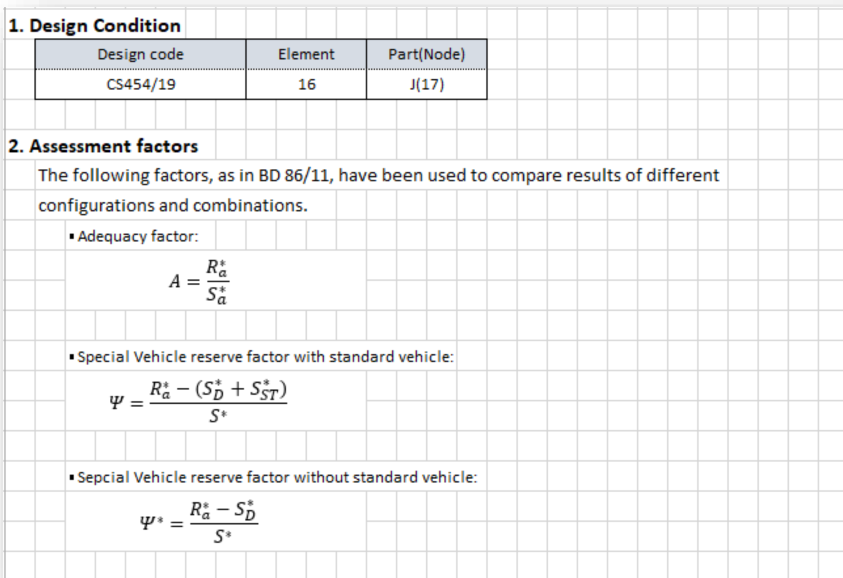
5. Update to CS 454 revision 1 for the UK Bridge Assessment

- CS 454 revision 1 Assessment of highway bridges and structures
- The existing CS454/19 is replaced by CS454/20. References in the report are changed from BD 86/11, BD 44/15 to CS 458, CS 455, respectively.

- ***Rating > Bridge Rating Design > PSC Bridge> Design Code for Assessment***







1. Design Condition

Design code	Element	Part(Node)
CS454/19	16	J(17)

2. Assessment factors

The following factors, as in BD 86/11, have been used to compare results of different configurations and combinations.

- Adequacy factor:

$$A = \frac{R_a^*}{S_a^*}$$

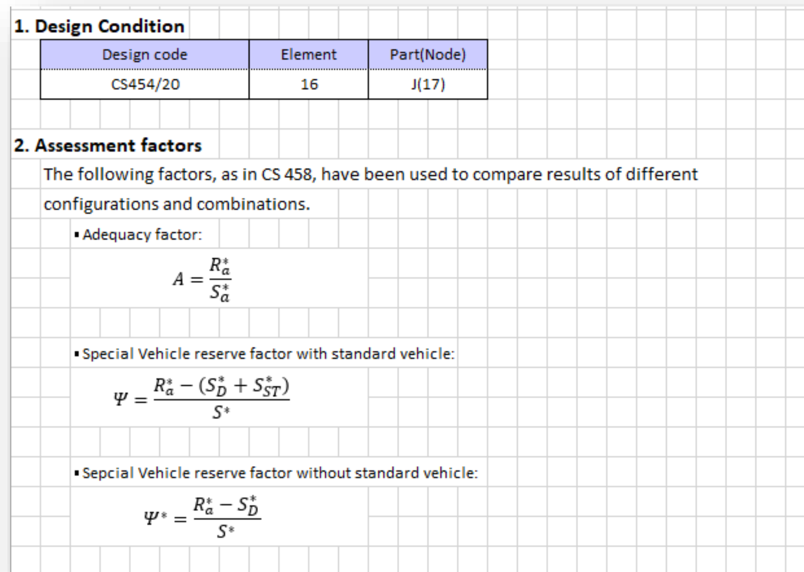
- Special Vehicle reserve factor with standard vehicle:

$$\Psi = \frac{R_a^* - (S_D^* + S_{ST}^*)}{S^*}$$

- Sepcial Vehicle reserve factor without standard vehicle:

$$\Psi^* = \frac{R_a^* - S_D^*}{S^*}$$

CS 454/19 Report



1. Design Condition

Design code	Element	Part(Node)
CS454/20	16	J(17)

2. Assessment factors

The following factors, as in CS 458, have been used to compare results of different configurations and combinations.

- Adequacy factor:

$$A = \frac{R_a^*}{S_a^*}$$

- Special Vehicle reserve factor with standard vehicle:

$$\Psi = \frac{R_a^* - (S_D^* + S_{ST}^*)}{S^*}$$

- Sepcial Vehicle reserve factor without standard vehicle:

$$\Psi^* = \frac{R_a^* - S_D^*}{S^*}$$

CS 454/20 Report

5. Update to CS 454 revision 1 for the UK Bridge Assessment

- Changes in CS 455: The assessment of concrete highway bridges and structures (formerly BD 44/15)

1) The compressive stress limit of composite beam is changed.

4.8.2 Stress Limit

a) Non-composite sections:

The compressive stress must be limited to $0.5(f_{cu}/\gamma_{mc})$.

b) Composite sections:

The maximum compressive stress limit can be taken as equal to $0.625\ (f_{cu}/\gamma_{mc})$.

BD 44/15

Table 8.15a SLS classes for prestressed elements

SLS class	Tensile stress limits[1,2]	Compressive stress limits[3,4]
SLS Class 1	$\sigma_{ct} < 0$	$\sigma_c < 0.5\frac{f_{cu}}{\gamma_{mc}}$
SLS Class 2	$0 \leq \sigma_{ct} < \frac{0.56}{\gamma_{mc}}\sqrt{f_{cu}}$	$\sigma_c < 0.5\frac{f_{cu}}{\gamma_{mc}}$
SLS Class 3	The tensile stresses in the concrete do not satisfy SLS Class 2 but either of the following are satisfied: 1) hypothetical tensile stresses are assessed to be less than the equivalent limits given in Table 8.15b; or, 2) an assessment of crack widths demonstrates that crack widths satisfy SLS design requirements for durability.	$\sigma_c < 0.5\frac{f_{cu}}{\gamma_{mc}}$

CS 455

5. Update to CS 454 revision 1 for the UK Bridge Assessment

2) The tensile stress limit of pre-tensioned class 3 members is changed.

Table 4-5 Hypothetical flexural tensile stresses for class 3 members

	Limiting crack width	Stress for concrete grade 30	40	50 and over
	mm	N/mm^2	N/mm^2	N/mm^2
a) Pre-tensioned tendons	0.1	-	4.1	4.8
	0.15	-	4.5	5.3
	0.25	-	5.5	6.3
b) Grouted post-tensioned ten				
c) Pre-tensioned tendons distr the tensile zone and positione the tension faces of the concr				

BD 44/15

Table 8.15b Hypothetical tensile stress limits for SLS Class 3

		Hypothetical tensile stress limits for a member of 400mm depth[2]		
Prestressing type	**Surface environment[1]**	f_{cu} =30 MPa	f_{cu} =40 MPa	f_{cu} ≥50 MPa
Pre-tensioned tendons / grouted post-tensioned tendons	Extreme	-	4.1	4.8
	Very severe	3.5	4.5	5.3
	Severe / Moderate	4.1	5.5	6.3
Pre-tensioned tendons distributed in the tensile zone and positioned close to the tension faces of the concrete	Extreme	-	5.3	6.3
	Very severe	-	5.8	6.8
	Severe / Moderate	-	6.8	7.8

Note 1: The surface environment is defined in Table 8.15c for the surface in tension.
Note 2: The hypothetical tensile stress limits are applicable for a member of 400mm depth. For other depths, the stress limits should be multiplied by the depth factor in Table 8.15d.
Note 3: The hypothetical tensile stress limits are based on the analysis of a notionally uncracked section where plane sections are assumed to remain plane and the concrete is assumed to have linear elastic properties in tension and compression up to the hypothetical stress limits.
Note 4: The hypothetical tensile stress limits are not applicable for unbonded tendons; prestressed structures containing exclusively unbonded tendons need not to be checked for cracking, and those containing both bonded and unbonded tendon are treated as reinforced concrete sections in which the effect of prestress is an axial force and moment, and crack widths are calculated as reinforced concrete columns.
Note 5: The hypothetical tensile stress limits conservatively ignore the effect of additional tensile reinforcement. The effect of additional tensile reinforcement is given in BS 5400-4 [Ref 19.I].

CS 455

5. Update to CS 454 revision 1 for the UK Bridge Assessment

3) When additional reinforcement is contained within the tension zone, the provision of increase in the tensile stress limit of pre-tensioned class 3 members is removed.

6.3.2.4 *Cracking*

When additional reinforcement is contained within the tension zone and positioned close to the tension faces of the concrete, these hypothetical tensile stresses may be increased by an amount that is proportional to the cross-sectional areas of the additional reinforcement expressed as a percentage of the cross-sectional area of the tensile concrete. For 1 % of additional reinforcement the stresses in Table 25 may be increased by 4.0 N/mm^2 for members in groups a) and b) and by 3.0 N/mm^2 for members in group c). For other percentages of additional reinforcement the stresses may be increased in proportion, except that the total hypothetical tensile stress should not exceed one-quarter of the characteristic cube strength of the concrete.

Where the hypothetical tensile stresses in Table 25 are to be increased to allow for additional reinforcement, and where the depth factors in Table 26 also apply, the values to be used should be obtained by first multiplying the basic stress from Table 25 by the appropriate factor from Table 26 and then adding the allowance for additional reinforcement.

BD 44/15 referring to BS 5400-4

→

Removed

CS 455

5. Update to CS 454 revision 1 for the UK Bridge Assessment

4) Some formulae for ULS shear check are changed.

5) The vertical component of the prestressing force may be added to Vmax as per clause 8.20.2. Additional option is introduced to consider this change.

ULS Shear check

$$V_{max} = (0.36(0.7 - f_{cu}/250)\, f_{cu}/\gamma_{mc}) b d_s$$

$$V_{co} = \frac{Ib}{S}\sqrt{f_t^2 + \sigma_{cpb} f_t}$$

$$V_{cr} = (1 - 0.55\, f_{pe}/f_{pu}) v_c b d_s + M_o/(M/V - d_s/2)$$

$$\frac{M}{z} + \frac{(V - \xi_s v_c b_w d)}{2}$$

BD 44/15

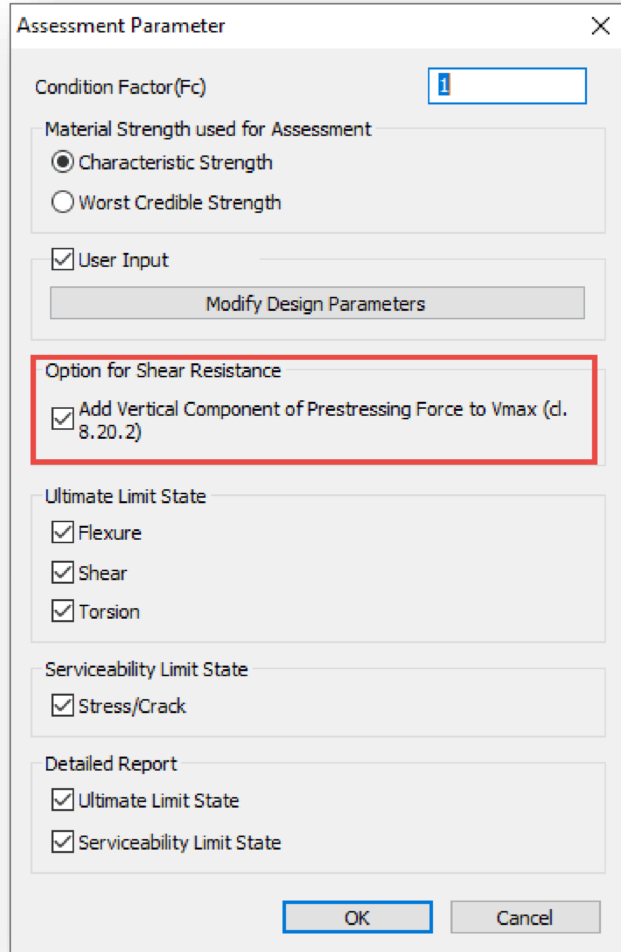
$$V_{\max} = 0.36\left(0.7 - \frac{f_{cu}}{250}\right)\left(\frac{f_{cu}}{\gamma_{mc}}\right) b_w d + P_v$$

$$V_{co} = 0.67bh\sqrt{f_t^2 + \sigma_{cp} f_t}$$

$$V_{cr2} = \left(1 - 0.55\frac{f_{pe}}{f_{pu}}\right) V_{uc'} + \frac{M_0}{M/V - d/2}$$

$$A_{st}\frac{f_{put}}{\gamma_{ms}} + A_{su}\frac{f_{yu}}{\gamma_{ms}} \geq \frac{M}{z} + \frac{V - V_{uc}}{2}(1 - \cot\alpha)$$

CS 455

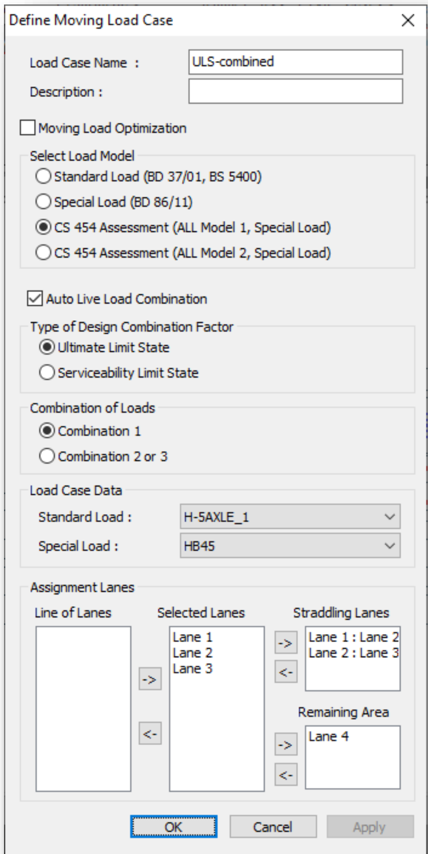


Option in Assessment Parameter

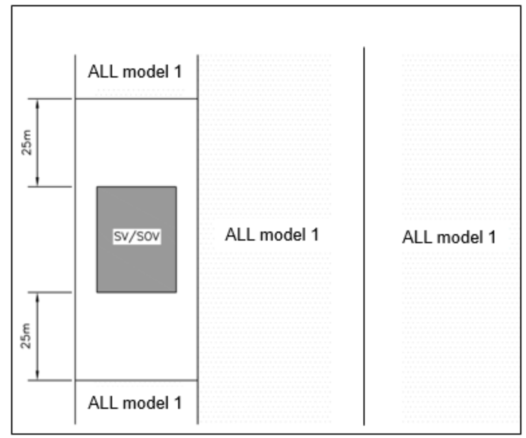
6. Application of Combined Special Vehicle and ALL model 1 for CS 454 Assessment

- CS 454: Assessment of highway bridges and structures
- ALL mode 1 (single or convoy) can be applied along with special vehicle or HB load.

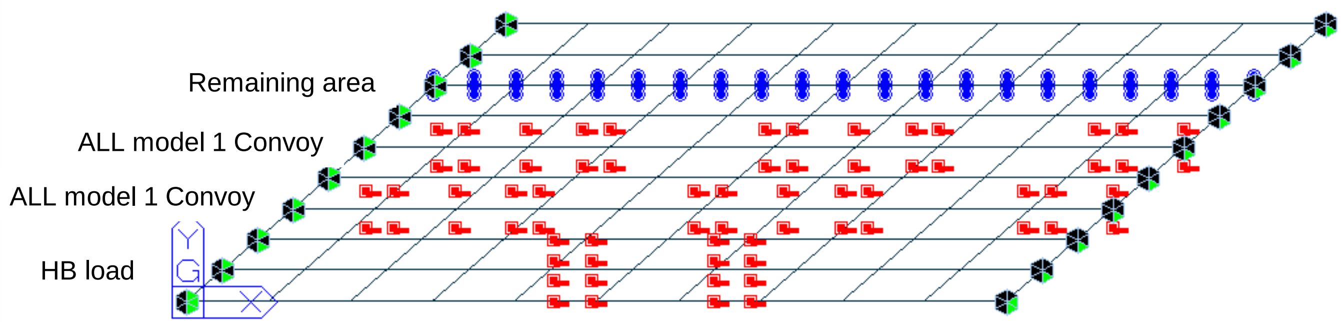
- ***Load > Moving Load Code> BS***
- ***Load > Moving Load Analysis Data> Moving Load Cases***



Moving Load Case Dialog Box



Combined SV and ALL model 1

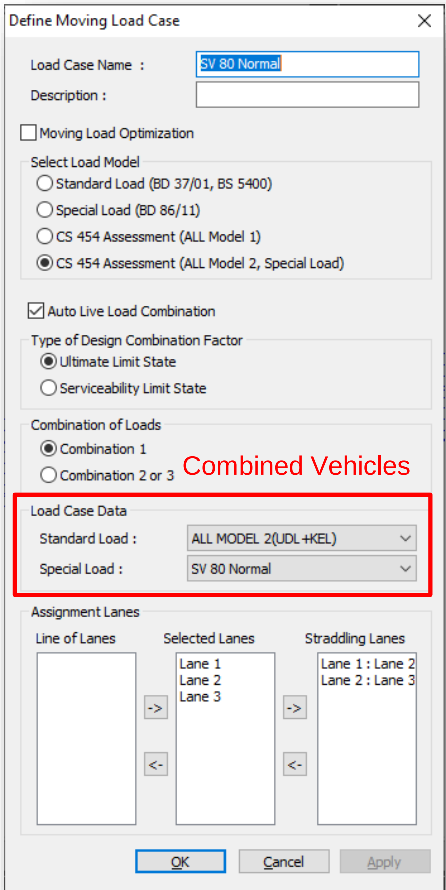


Moving Load Tracer

7. Separate the Results of Combined Vehicles for CS 454 Assessment

- The results of combined special vehicle and ALL model can be viewed separately by vehicles.
- This is useful when calculating reserve factors for special vehicles applied together with ALL model 1 or 2.

- ***Load > Moving Load Code> BS***



Moving Load Case

Results > Result Tables > Beam > Forces

Elem	Load	Part	Axial (kN)	Shear-y (kN)	Shear-z (kN)	Torsion (kN·m)	Moment-y (kN·m)	Moment-z (kN·m)
1	ULS-combined(max)	I[1]	729.73	10.91	0.00	19.71	874.94	13.47
1	ULS-combined(max)	J[2]	729.73	10.91	0.00	19.71	2142.31	205.19
2	ULS-combined(max)	I[2]	624.96	17.12	40.42	18.02	2096.93	35.66
2	ULS-combined(max)	J[3]	624.96	17.12	40.42	18.02	3716.00	105.83
3	ULS-combined(max)	I[3]	577.18	25.54	73.49	0.78	3660.09	39.48
3	ULS-combined(max)	J[4]	577.18	25.54	73.49	0.78	4814.77	148.97

Beam Force

View by Max Value

Elem	Load	Part	Component	Axial (kN)	Shear-y (kN)	Shear-z (kN)	Torsion (kN·m)	Moment-y (kN·m)	Moment-z (kN·m)
1	ULS-combined(max)	I[1]	Moment-y	729.73	10.49	0.00	19.71	610.40	13.47
1	ULS-combined(max)	J[2]	Moment-y	729.73	10.49	0.00	19.71	1490.96	142.59
2	ULS-combined(max)	I[2]	Moment-y	624.96	16.48	40.42	18.02	1534.39	28.40
2	ULS-combined(max)	J[3]	Moment-y	624.96	16.48	40.42	18.02	2991.74	91.46
3	ULS-combined(max)	I[3]	Moment-y	577.18	25.51	73.49	0.00	2990.64	38.52
3	ULS-combined(max)	J[4]	Moment-y	577.18	25.51	73.49	0.00	3965.49	100.88

Result By Max Value-[Beam Force] / Result By Max Value-[Beam Force]_Standard / Result By Max Value-[Beam Force]_Special

View by Load Cases

Elem	Part	ULS-combined	ULS-combined_Standard	ULS-combined_Special
		max	max	max
Output:Moment-y(kN·m)				
1	I	874.94	264.55	610.40
1	J	2142.31	651.35	1490.96
2	I	2096.93	562.54	1534.39
2	J	3716.00	724.25	2991.74
3	I	3660.09	669.45	2990.64
3	J	4814.77	849.28	3965.49

Moment-y

S^*_{ST} S^*

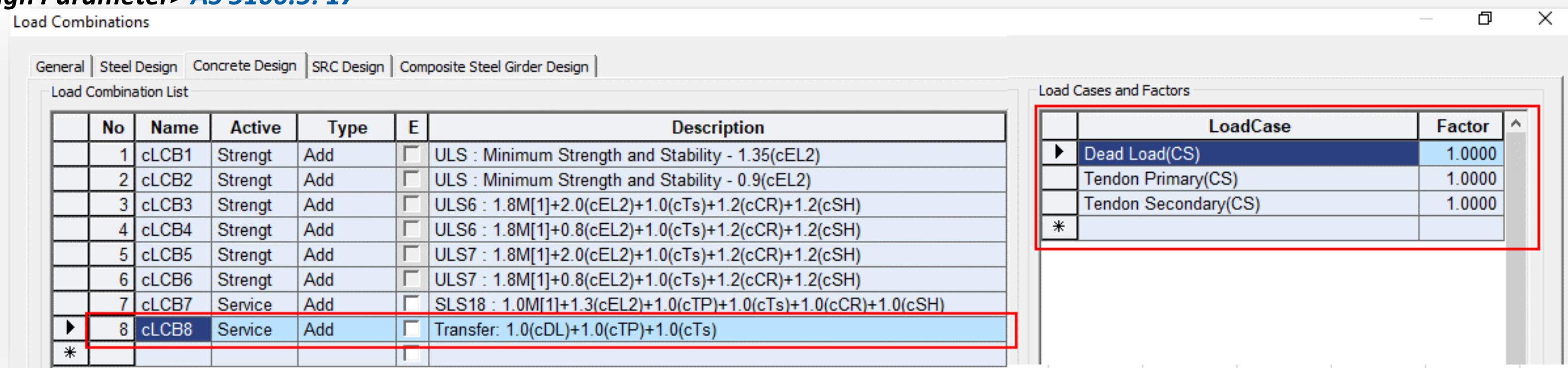
- SV reserve factor

$$\Psi_{SV} = \frac{R^*_A - (S^*_D + S^*_{ST})}{S^*}$$

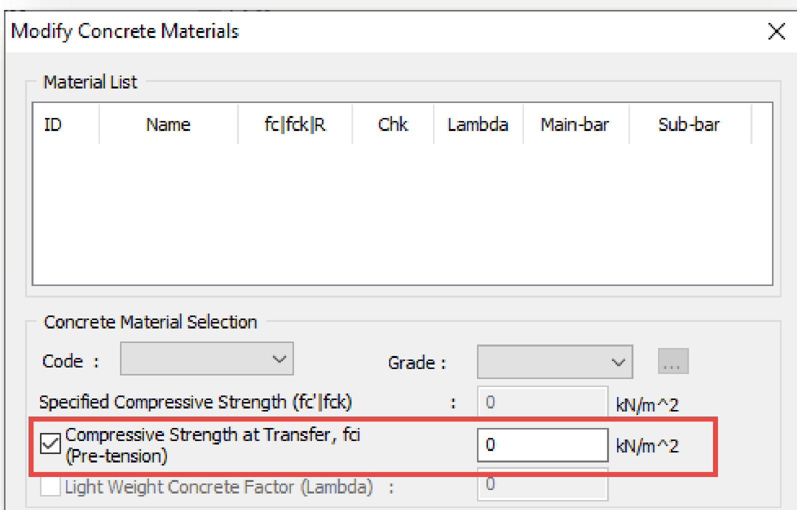
8. Pretensioned Beam Design at Transfer to AS 5100.5

- Pretensioned beam design at transfer is provided as per clause 8.1.6.2 and 8.6.2 of AS 5100.5.
- Load combination type for transfer check is added.
- Compressive strength, fcp during transfer needs to be defined manually for the design checks.

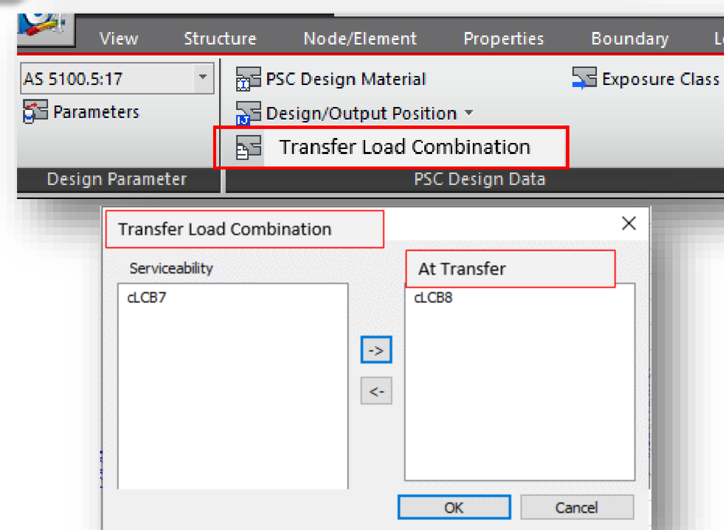
- ***PSC > Design Parameter> AS 5100.5: 17***



Load Combination



Manual input option for strength at transfer



Transfer Load Combination

8. Pretensioned Beam Design at Transfer to AS 5100.5

- Compressive stress of concrete and crack control are checked.
- Excel report and table summary are provided.

■ ***PSC > Design Parameter> AS 5100.5: 17***

2. Transfer check

- Transfer stage : at CS1

1) Concrete compressive stress check

■ **Top**

- Load combination at transfer: cLCB14
- Stress at top surface (Concrete)

ft = 14.86 (MPa)

- Stress limit

$0.6\,f_{cp}$ = 19.20 (MPa)

f_{cp} = 32.00 (MPa)

- Check Stress

f_i = 14.86 (MPa) ≤ $0.6\,f_{cp}$ = 19.20 (MPa) OK

2) Crack control

■ **Bottom** $0.25\sqrt{f'_c}$

- Exposure class : A
- Maximum service limit load combination : cLCB14
- Maximum service limit load combination type: -
- Stress at bottom surface (Concrete)

fb = 4.08 (MPa)

1) Crack control for flexure in prestressed beams (General)

▪ Maximum stress analysis at surface (see. 8.6.2.1)

$f_{surface}$ = 4.08 (MPa) > $0.25\sqrt{f'_c}$ = 1.58 (MPa)

∴ Since maximum tensile stress is exceeded, spacing check consideration is needed.

Transfer Check in Excel Report

Elem	Part	LCom Name	CHK	FT (N/mm²)	FB (N/mm²)	FTL (N/mm²)	FBL (N/mm²)	FTR (N/mm²)	FBR (N/mm²)	FMAX (N/mm²)	ALW (N/mm²)
2	I[2]	cLCB14	OK	2.5999	7.4502	2.5999	7.4502	2.5999	7.4502	7.4502	19.2000
2	J[3]	cLCB14	OK	6.2791	3.9898	6.2791	3.9898	6.2791	3.9898	6.2791	19.2000
3	I[3]	cLCB14	OK	6.2791	3.9898	6.2791	3.9898	6.2791	3.9898	6.2791	19.2000
3	J[4]	cLCB14	OK	9.3452	1.1061	9.3452	1.1061	9.3452	1.1061	9.3452	19.2000
4	I[4]	cLCB14	OK	9.3452	1.1061	9.3452	1.1061	9.3452	1.1061	9.3452	19.2000
4	J[5]	cLCB14	OK	11.7980	-1.2009	11.7980	-1.2009	11.7980	-1.2009	11.7980	19.2000
5	I[5]	cLCB14	OK	11.7980	-1.2009	11.7980	-1.2009	11.7980	-1.2009	11.7980	19.2000
5	J[6]	cLCB14	OK	13.6376	-2.9311	13.6376	-2.9311	13.6376	-2.9311	13.6376	19.2000
6	I[6]	cLCB14	OK	13.6376	-2.9311	13.6376	-2.9311	13.6376	-2.9311	13.6376	19.2000
6	J[7]	cLCB14	OK	14.8641	-4.0846	14.8641	-4.0846	14.8641	-4.0846	14.8641	19.2000
7	I[7]	cLCB14	OK	14.8641	-4.0846	14.8641	-4.0846	14.8641	-4.0846	14.8641	19.2000
7	J[8]	cLCB14	OK	15.4773	-4.6613	15.4773	-4.6613	15.4773	-4.6613	15.4773	19.2000
8	I[8]	cLCB14	OK	15.4773	-4.6613	15.4773	-4.6613	15.4773	-4.6613	15.4773	19.2000
8	J[9]	cLCB14	OK	15.4773	-4.6613	15.4773	-4.6613	15.4773	-4.6613	15.4773	19.2000
9	I[9]	cLCB14	OK	15.4773	-4.6613	15.4773	-4.6613	15.4773	-4.6613	15.4773	19.2000
9	J[10]	cLCB14	OK	14.8641	-4.0846	14.8641	-4.0846	14.8641	-4.0846	14.8641	19.2000
10	I[10]	cLCB14	OK	14.8641	-4.0846	14.8641	-4.0846	14.8641	-4.0846	14.8641	19.2000

\Check Compressive Stress at Transfer /

Check Compressive Stress at Transfer

Elem	Part	Top/Bottom	LCom Name	CHK	ft (N/mm²)	fb (N/mm²)	0.25*sqrt(fc') (N/mm²)	0.5*sqrt(fc') (N/mm²)	s (mm)	s_max (mm)	fs (N/mm²)	fsa (N/mm²)
1	I[1]	Bottom	cLCB14	OK	1.6926	-11.4874	1.5811	3.1623	0.0000	200.0000	-59.3296	160.0000
1	J[2]	Bottom	cLCB14	OK	-2.5999	-7.4502	1.5811	3.1623	0.0000	200.0000	-41.4847	160.0000
2	I[2]	Bottom	cLCB14	OK	-2.5999	-7.4502	1.5811	3.1623	0.0000	200.0000	-41.4847	160.0000
2	J[3]	Bottom	cLCB14	OK	-6.2791	-3.9898	1.5811	3.1623	0.0000	200.0000	-26.1891	160.0000
3	I[3]	Bottom	cLCB14	OK	-6.2791	-3.9898	1.5811	3.1623	0.0000	200.0000	-26.1891	160.0000
3	J[4]	Bottom	cLCB14	OK	-9.3452	-1.1061	1.5811	3.1623	0.0000	200.0000	-13.4428	160.0000
4	I[4]	Bottom	cLCB14	OK	-9.3452	-1.1061	1.5811	3.1623	0.0000	200.0000	-13.4428	160.0000
4	J[5]	Bottom	cLCB14	OK	-11.7980	1.2009	1.5811	3.1623	0.0000	200.0000	-9.0974	160.0000
5	I[5]	Bottom	cLCB14	OK	-11.7980	1.2009	1.5811	3.1623	0.0000	200.0000	-9.0974	160.0000
5	J[6]	Bottom	cLCB14	NG	-13.6376	2.9311	1.5811	3.1623	0.0000	200.0000	14.2382	160.0000

\Check Crack Control at Transfer /

Check Crack Control at Transfer

9. Transmission Zone Design of Pretensioned Beam to AS 5100.5

- Pretensioned beam design is performed considering stress development in tendons as a bi-linear relationship defined by the transmission length and development length as per AS 5100.5.
- Flexural resistance at ULS within development length.

■ ***PSC > Design Parameter> AS 5100.5: 17***

2.Flexure design for a section

■ **Moment Direction : Positive**

- Method of calculation : Strain compatibility
- Maximum strength limit load combination : cLCB3
- Maximum strength limit load combination type : -
- Maximum factored moment (M*) : 243.25 (kN·m)

No.	Axial force in tendons(Bond) by strain compatibility				
	Tendon name	ε_{ps}	f_{ps} (MPa)	$T_{ps}=A_{ps}f_{ps}$ (kN)	$A_{ps}f_{ps}(d_p-c)$ (kN·m)
1	S_Span1-223	0.129213	1458.66	204.21	321.91
2	S_Span1-222	0.129212	1458.36	204.17	321.85
3	S_Span1-221	0.129208	1457.76	204.09	321.71
4	S_Span1-224	0.129215	1458.96	204.25	321.98
			Σ		

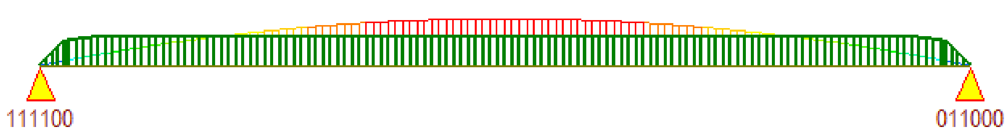
Tendon stress at ULS within development length

No.	Development Length				
	Tendon name	L_{pt} (mm)	L_p (mm)	L (mm)	f_{pu} (MPa)
1	S_Span1-223	800.00	1505.98	1000.00	1667.16
2	S_Span1-222	800.00	1506.43	1000.00	1667.16
3	S_Span1-221	800.00	1507.33	1000.00	1667.16
4	S_Span1-224	800.00	1505.53	1000.00	1667.16

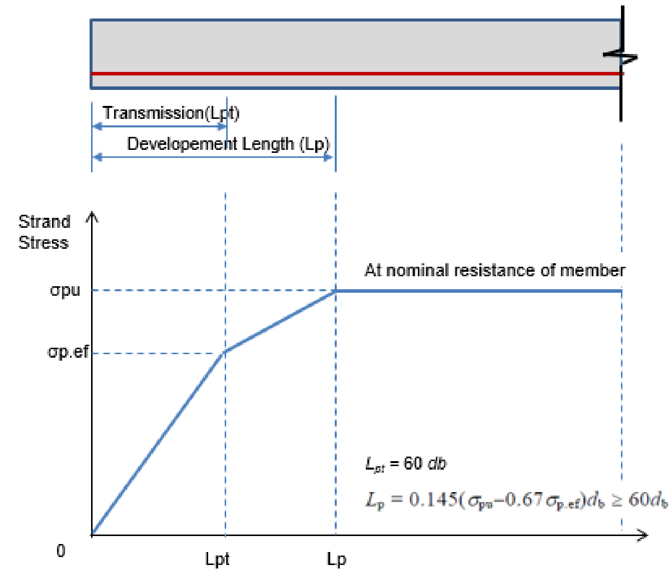
* The section is located within the development length

Transfer Length & Development Length

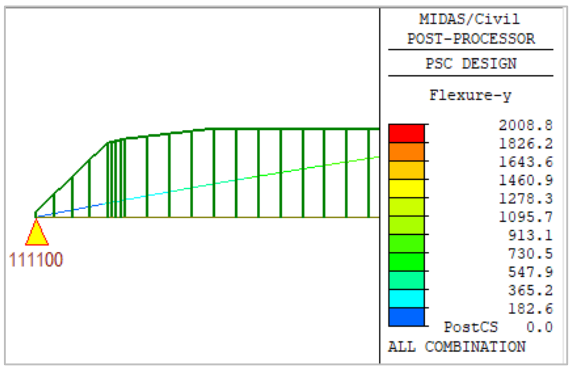
Development Length in Report



Flexural Resistance Diagram



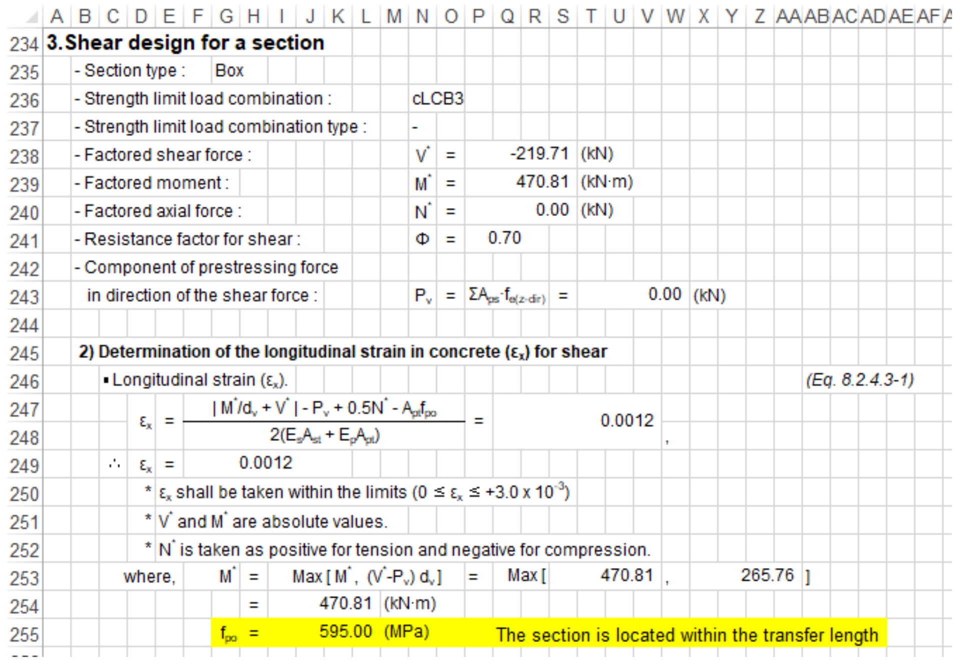
Stresses in the Tendon at ULS



9. Transmission Zone Design of Pretensioned Beam to AS 5100.5

- Shear resistance at ULS within transmission length.

- ***Load > Temp./Prestress > Tendon Profile***



3. Shear design for a section

- Section type : Box
- Strength limit load combination : cLCB3
- Strength limit load combination type : -
- Factored shear force : $V^* = -219.71$ (kN)
- Factored moment : $M^* = 470.81$ (kN·m)
- Factored axial force : $N^* = 0.00$ (kN)
- Resistance factor for shear : $\Phi = 0.70$
- Component of prestressing force in direction of the shear force : $P_v = \Sigma A_{ps} \cdot f_{e(z\text{-}dir)} = 0.00$ (kN)

2) Determination of the longitudinal strain in concrete (ε_x) for shear

▪ Longitudinal strain (ε_x). *(Eq. 8.2.4.3-1)*

$$\varepsilon_x = \frac{|M^*/d_v + V^*| - P_v + 0.5N^* - A_{pt}f_{po}}{2(E_sA_{st} + E_pA_{pt})} = 0.0012$$

$\therefore \varepsilon_x = 0.0012$

* ε_x shall be taken within the limits ($0 \le \varepsilon_x \le +3.0 \times 10^{-3}$)

* V^* and M^* are absolute values.

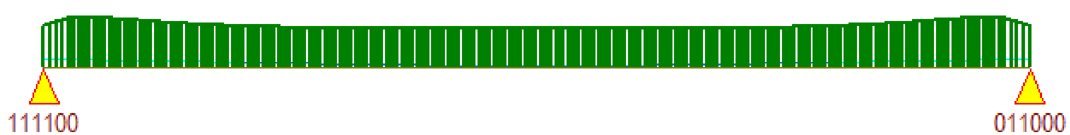
* N^* is taken as positive for tension and negative for compression.

where, $M^* = \mathrm{Max}[M^*, (V^*-P_v)d_v] = \mathrm{Max}[470.81, 265.76]$

$= 470.81$ (kN·m)

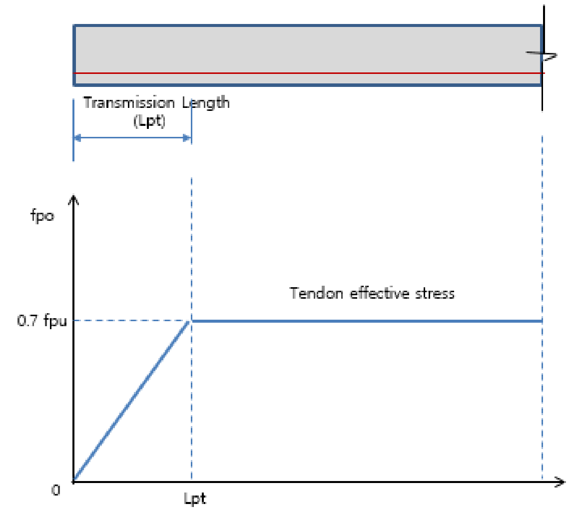
$f_{po} = 595.00$ (MPa) The section is located within the transfer length

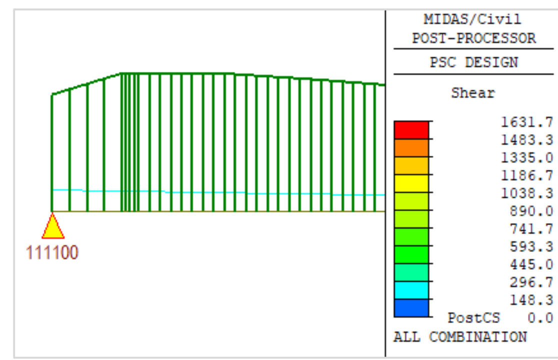
Tendon stress fpo within transfer length



Shear Resistance Diagram

- ***Stress in prestressed tendon when stress in surrounding concrete is zero***

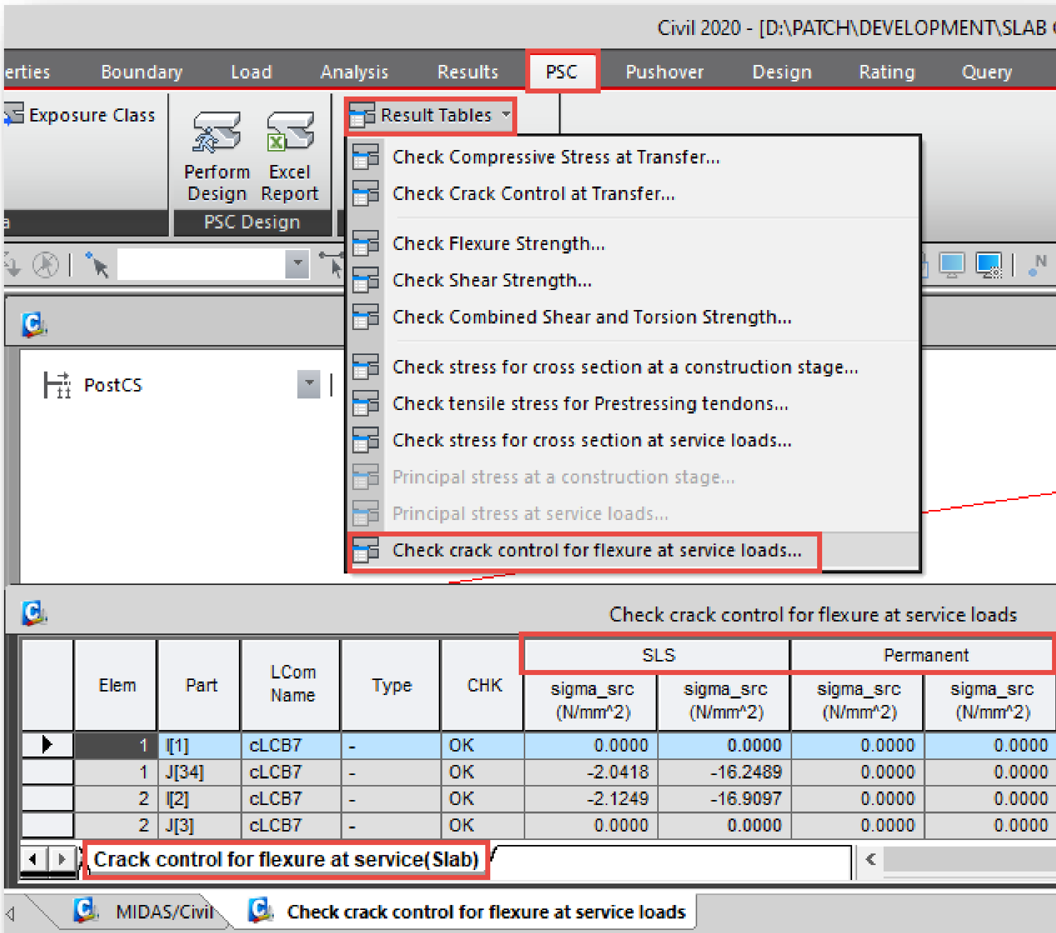




10. Crack Control for the Slab of PSC Composite Girder to AS5100.5

- Slab crack control as per clause 8.6.1. is provided for PSC composite beams. Slab crack review controlled primarily in flexure at the top of the Slab.

- ***PSC > Design Parameter> AS 5100.5***



- **Load Effect considered for two cases:-**
- **a) SLS Load Combination**
- **b) For Beams designed for exposure classifications B2, C1, C2, and U, permanent effects at the SLS.**

Rebar stress limit based on 8.6.1 (A), (B).

10. Crack control for flexure at Service for the Slab of PSC Composite Beam to AS5100.5

- For rebar stress check due to SLS load combination, rebar stress for Exposure class A, B1 compared with left column stress limit value of Table 8.6.1 (A), (B).
- For Rebar stress check due to permanent effects at the SLS, rebar stress for Exposure class B2, C1, C2 and U, compared with right column stress limit value of Table 8.6.1 (A), (B).

- ***PSC > Design Parameter> AS 5100.5***

1) Rebar stress check due to SLS load combination				*(see. 8.6.1)*
- Calculated rebar stress				
σ_{scr} =	-16.25 (MPa)			
▪ Neutral axis depth from the extreme compression fiber.				
d_{NA} =	552.48 (mm)			
- Equilibrium forces				
(Compression)				
- Prestress =	770.52 (kN)			
- Reinforcement =	-12.09 (kN)			
- Concrete =	0.00 (kN)			
(Tension)				
- Prestress =	0.00 (kN)			
- Reinforcement =	198.10 (kN)			
- Rebar stress limit				
- Stress limit by rebar diameter				*(See Table 8.6.1(A))*
d_b =	28.00 (mm)	f_{scr1} =	183.53 (MPa)	
- Stress limit by rebar spacing				*(See Table 8.6.1(B))*
s =	0.00 (mm)	f_{scr2} =	200.00 (MPa)	
- Maximum stress limit				
f_{scr} = max(f_{scr1}, f_{scr2}) =	200.00 (MPa)			
- Rebar stress limit check				
σ_{scr} =	-16.25 (MPa) ≤	f_{scr} =	200.00 (MPa)	OK

Rebar Stress under Negative Moment (SLS)

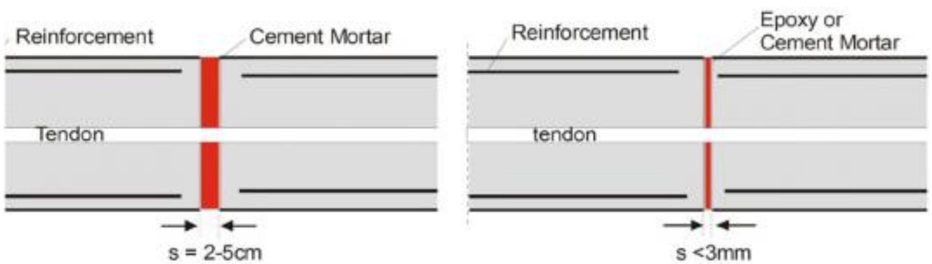
2) Rebar stress check due to permanent effects at the SLS				*(see. 8.6.1)*
- Calculated rebar stress				
σ_{scr} =	0.00 (MPa)			
▪ Neutral axis depth from the extreme compression fiber.				
d_{NA} =	0.00 (mm)			
- Equilibrium forces				
(Compression)				
- Prestress =	0.00 (kN)			
- Reinforcement =	0.00 (kN)			
- Concrete =	0.00 (kN)			
(Tension)				
- Prestress =	0.00 (kN)			
- Reinforcement =	0.00 (kN)			
- Rebar stress limit				
- Stress limit by rebar diameter				*(See Table 8.6.1(A))*
d_b =	28.00 (mm)	f_{scr1} =	141.81 (MPa)	
- Stress limit by rebar spacing				*(See Table 8.6.1(B))*
s =	0.00 (mm)	f_{scr2} =	280.00 (MPa)	
- Maximum stress limit				
f_{scr} = max(f_{scr1}, f_{scr2}) =	280.00 (MPa)			
- Rebar stress limit check				
σ_{scr} =	0.00 (MPa) ≤	f_{scr} =	280.00 (MPa)	OK

Rebar Stress under Negative Moment (Permanent Effect of SLS)

11. Joint Check of Segmental Construction to BS 5400.4

- Shear check and stress check at the joint of segmental construction are provided as per clause 6.3.4.6 and 7.3.3 of BS 5400.4, respectively.

- ***PSC > Design Parameter> BS 5400.4***



$$0.7\ (\tan \alpha_2) \cdot \gamma_{fL} \cdot P_h$$

where

γ_{fL} is the partial safety factor for the prestressing force, to be taken as 0.87;

P_h is the horizontal component of the force after losses appropriate to the construction stage under consideration or, in the case of the completed structure, after all losses.

α_2 is the angle of friction at the joint. Tan α_2 depends on the type of interface; for roughened and moistened segment faces a value of 0.7 may be adopted for erection phases, and 1.4 at completion.

Joint Shear Resistance

7.3.3 *Other types of connection.* Any other type of connection which can be capable of carrying the ultimate loads acting on it may be used subject to verification by test evidence. Amongst those suitable for resisting shear and flexure are those made by prestressing across the joint.

Resin adhesives, where tests have shown their acceptability, may be used to form joints subjected to compression but not to resist tension or shear.

For resin mortar joints, the flexural stresses in the joint should be compressive throughout under service loads. During the jointing operation at the construction stage, the average compressive stress between the concrete surfaces to be joined should be checked at the serviceability limit state and should lie between 0.2 N/mm^2 and 0.3 N/mm^2 measured over the total projection of the joint surface (locally not less than 0.15 N/mm^2) and the difference between flexural stresses across the section should be not more than 0.5 N/mm^2.

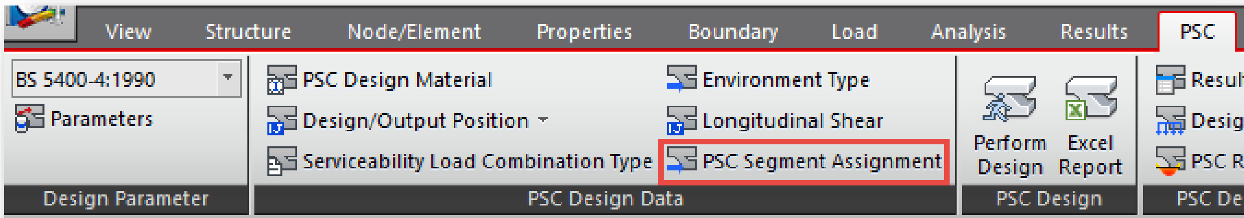
For cement mortar joints, the flexural stresses in the joint should be compressive throughout and not less than 1.5 N/mm^2 under service loads.

Joint Shear Stress Limit

11. Joint Check of Segmental Construction to BS 5400.4

- Segment Joint recognition is determined by the PSC Segment Assignment Function.

- ***PSC > Design Parameter> BS 5400.4***



- **Shear check provides two results: member shear review and joint shear review.**

5) **Joint Shear**

▪ Shear Resistance for Joint (V_u). *(see BS 5400 - 6.3.4.6)*

$V_u = 0.7(\tan\alpha_2)\gamma_{fL}P_h$ = 5643.43 (kN)

Where,

$\tan\alpha_2$: α2 is angle of friction at the joint
= 1.40

γ_{fL} : Partial safety factor for the prestressing force
= 0.87

P_h : Horizontal component of the prestress force after losses
= 6619.09 (kN)

▪ Shear Check

$V_u \geq V$

V_u = 5643.43 (kN) ≥ V = -1950.87 (kN) ∴ OK

Joint Shear Resistance

- **Serviceability check: the flexural stresses in the joint should be compressive through and stress limit is different depending upon Joint Type (Resin/Cement). 0 MPa is for resin and 1.5 MPa for cement.**

7. Joint stress check for service load combination

- Service limit load combination : cLCBDL1
- Service limit load combination type -

Joint Type : Resin mortar joints *(see BS 5400 - 7.3.3)*

σ_j : Compressive stress on the prestressed concrete
= 2.62 (MPa)

$\sigma_{j,limit}$: Stress Limit
= 0.00 (MPa)

Since

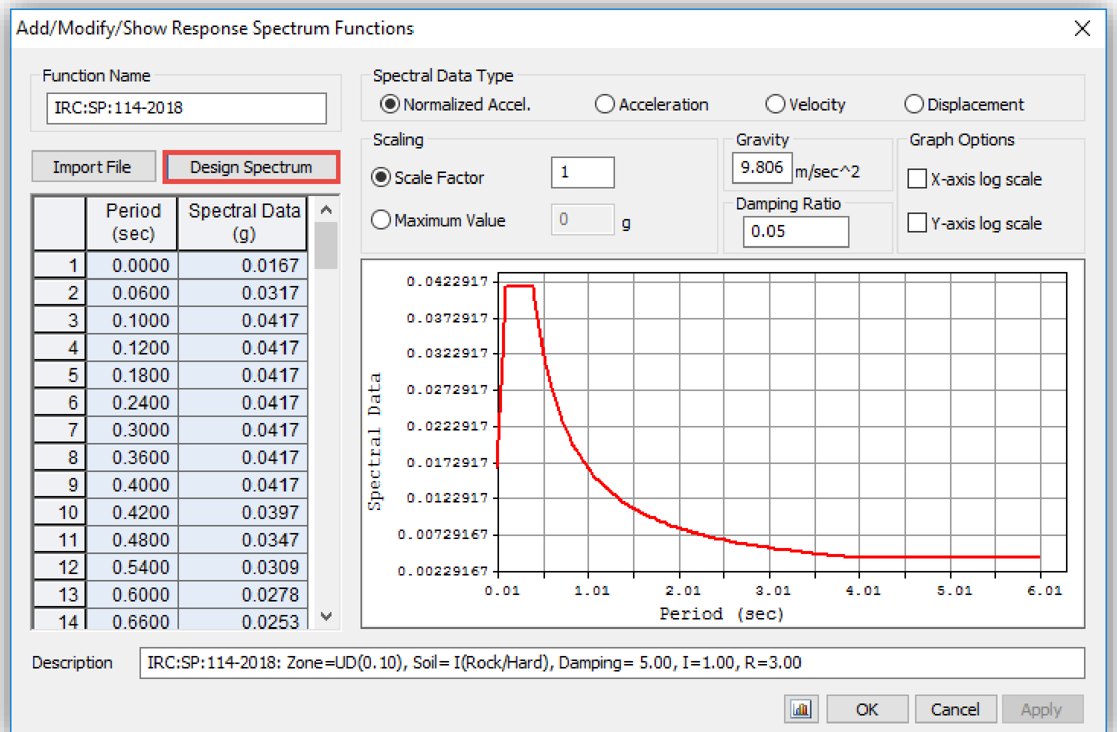
$\sigma_j > \sigma_{j,limit}$ ∴ OK

Joint Shear Stress Limit

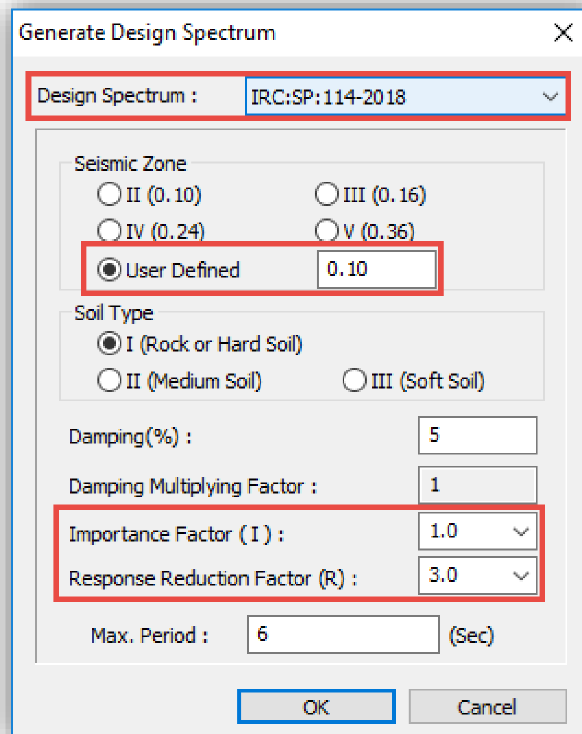
12. Response Spectrum Function : IRC SP 114:2018

- New response spectrum function guidelines for seismic design of road bridges as per IRC SP 114:2018
- In this version, the Response spectrum function can be modified as per user defined Zone Factor, Importance Factor and Response Reduction factor values
- Modification of Auto load combination as per IRC 6-2017 considering the response spectrum cases given in IRC SP 114:2018

- ***Load > Dynamic Loads > RS Functions***



Response Spectrum Functions

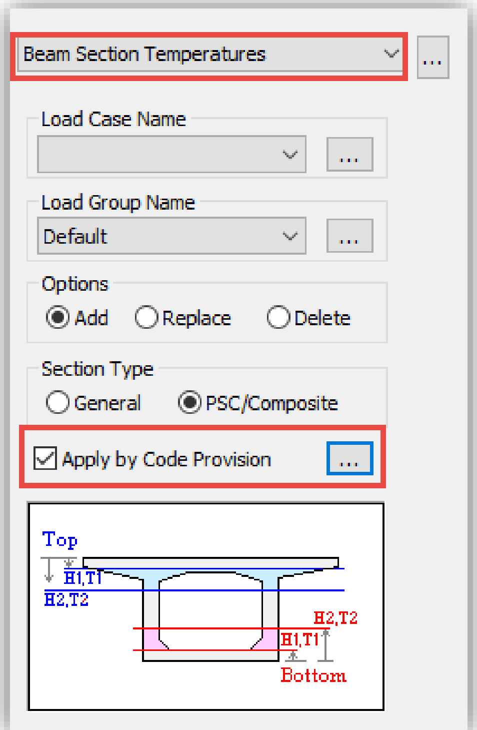


Design Spectrum inputs

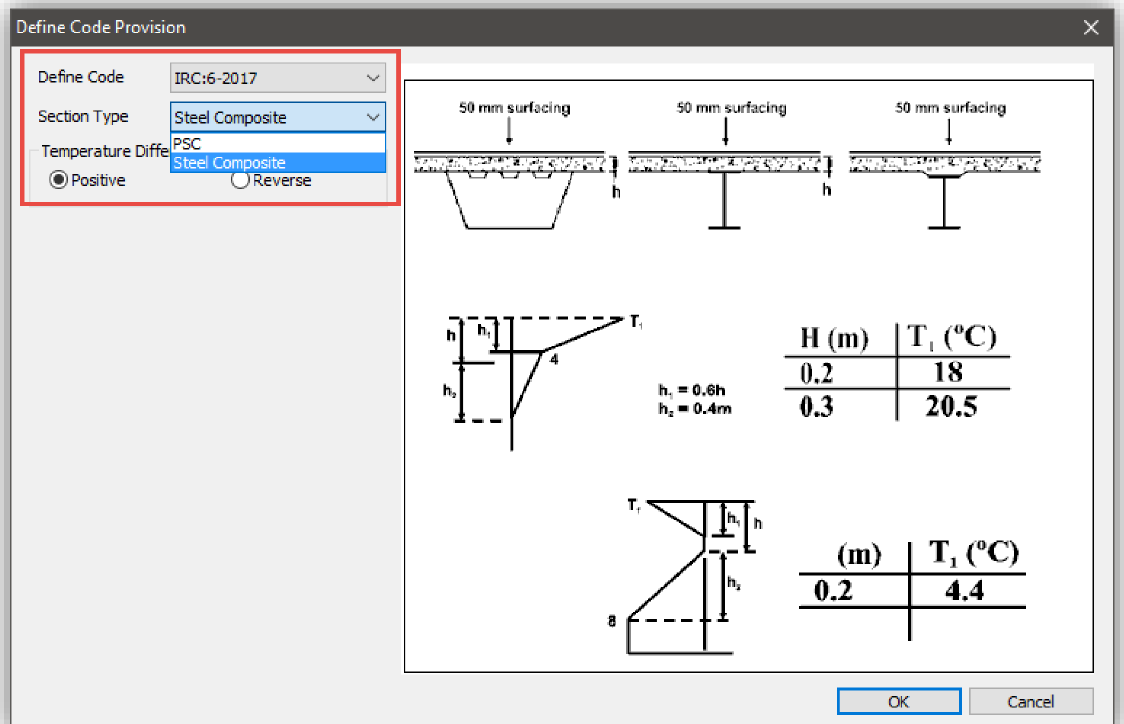
13. Auto Temperature Gradient as per IRC 6:2017

- Auto definition of Temperature Gradient for PSC and Steel composite girders as per IRC 6:2017.
- Applicable for section defined from PSC, Composite tab (not applicable for SPC and Value type sections).

- ***Load > Temp/Prestress> Beam Section Temperature***



Beam Section Temperature

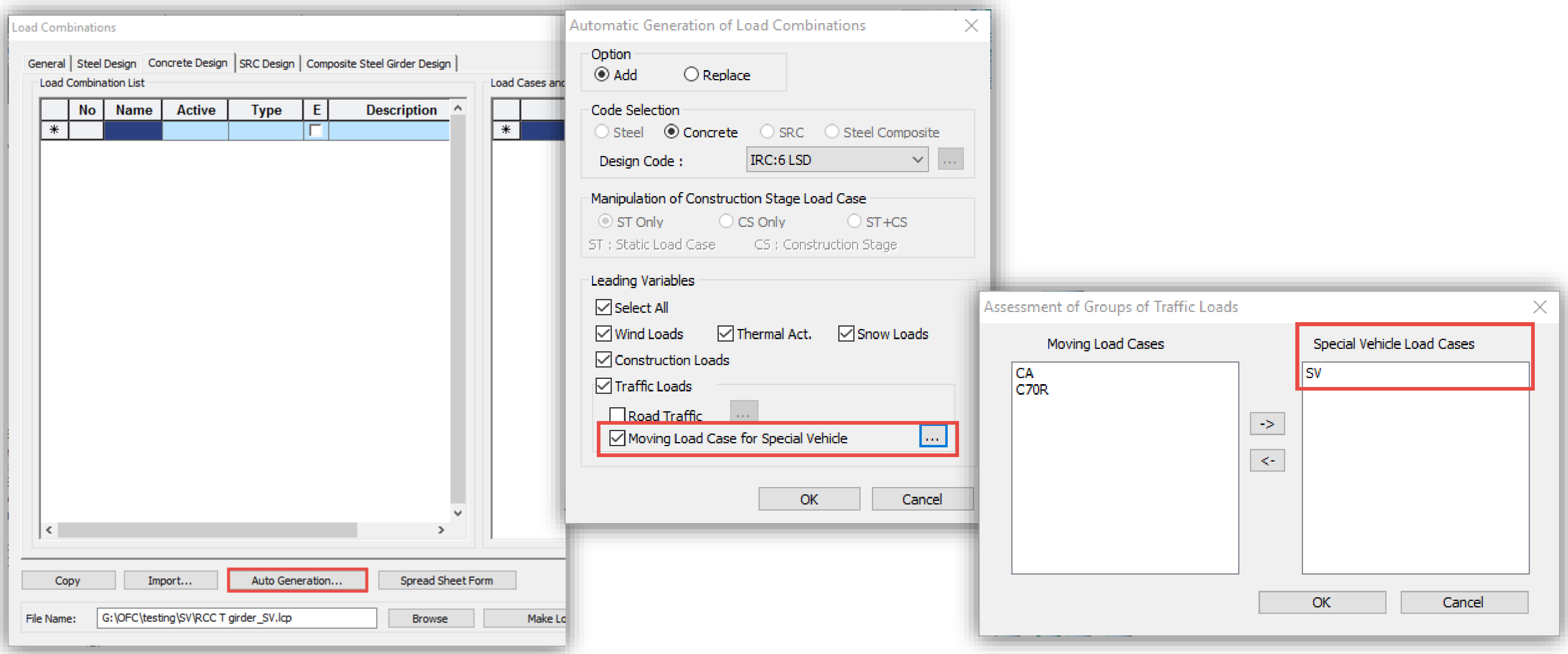


Auto option as per code provision

14. Improvement in Auto Load combinations as per IRC 6:2017

- Improvement in Auto Load combinations of Temperature load factors (Temperature uniform and Temperature gradient loads).
- Updates in load factors for combinations considered for Special Vehicle as per IRC 6:2017 Amendments.

- ***Results > Load Combinations > Auto Generation***



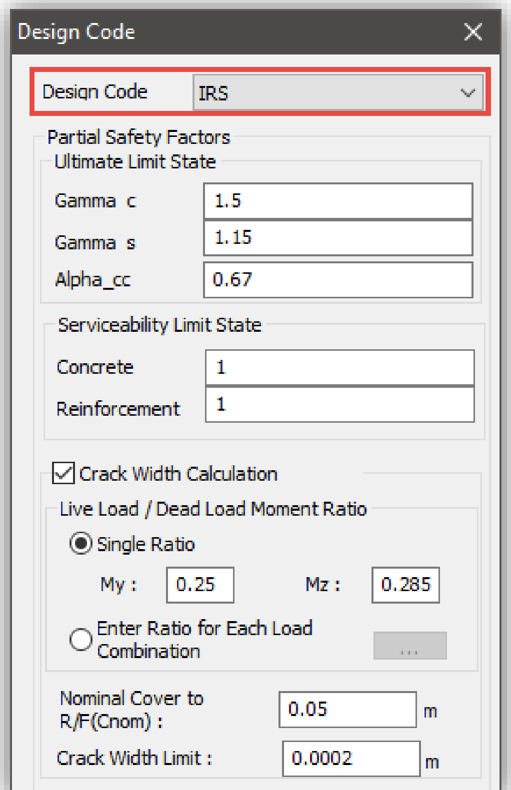
Auto Generation of Load Combination

Special Vehicle provision

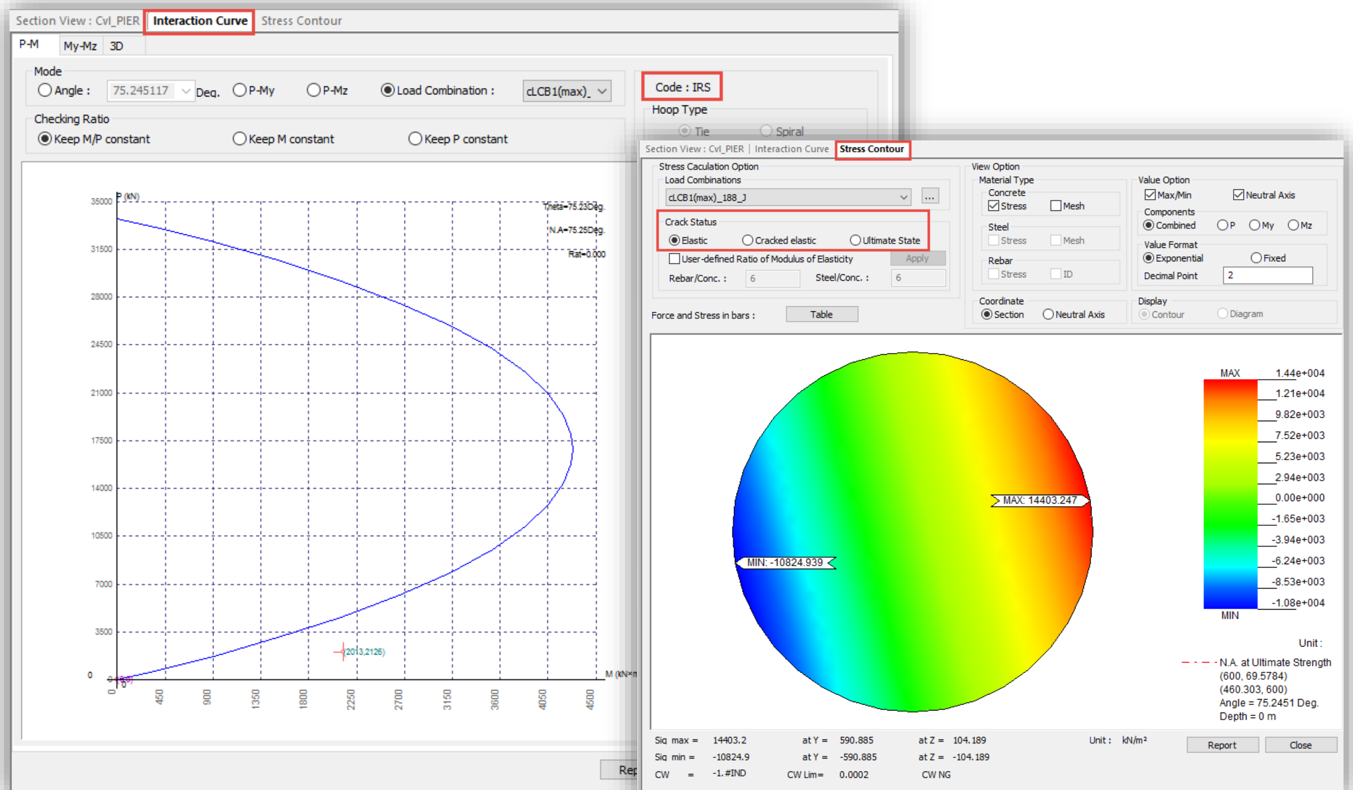
15. Update in General Section Designer as per IRS Specifications

- Ultimate check for P-M Interaction and Serviceability check for stresses and crack width as per IRS Concrete code.
- Improvement in material data base as per IRS Concrete code.

- ***Tools > General Section Designer***



Design parameter as per IRS



ULS and SLS Checks as per IRS