ECComBeam Composite Beam Design **Job :** Sample Report

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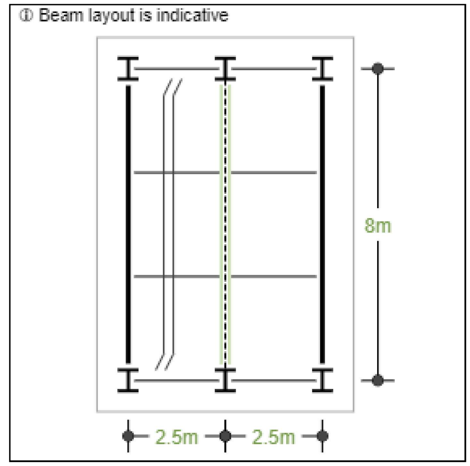
1.0 INPUT

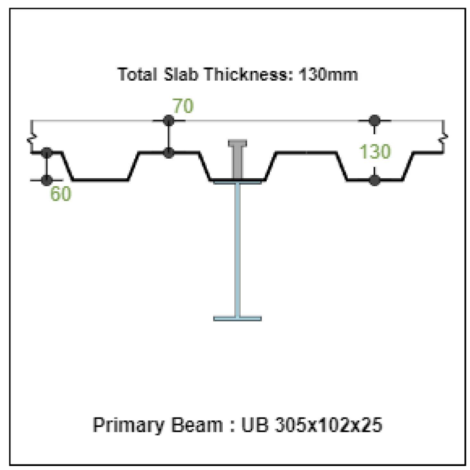


1.1 Design Options

Design Code			**American Standard LRFD**
Unit			**SI Unit**
Composite Design			**No**
Shored During Construction			**Yes**

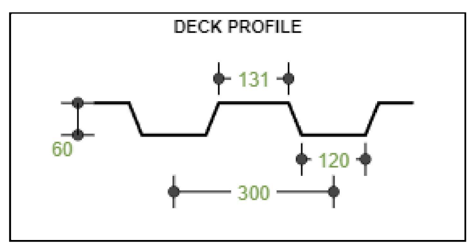
1.2 Beam

Beam Type			**Primary**
Beam location			**Intermediate**
Span	L	=	**8** m
Beam Spacing	b	=	**2.5** m



1.3 Deck and Slab Details

Deck Ribs Orientation			**Longitudinal**
Total Slab Depth	D_s	=	**130** mm
Mesh Area (Reinf.)	A_m	=	**193** mm²/m
Deck Depth	t	=	**60** mm
Trough Spacing	T_{rs}	=	**300** mm
Trough Width	T_{rw}	=	**120** mm
Crest Width	C_{rw}	=	**131** mm
Deck Thickness	t_d	=	**0.9** mm
Deck Weight	W_d	=	**0.103** kN/m²
Deck Area	A_d	=	**1276** mm²



1.4 Concrete Properties

Concrete Type			**Normal Weight**
Wet density of concrete	w_{cw}	=	**25.5** kN/m^3
Dry density of concrete	w_{cd}	=	**24.5** kN/m^3
Characteristic Strength	f_{cu}	=	**30** N/mm²
Longterm Modulus Reduction	L_{Rec}	=	**50** %

1.5 Steel Properties

Steel Grade	F_b	=	**A36**

Yield strength of Steel	F_y	= **248** N/mm²
Strength of Reinforcement	f_{yr}	= **420** N/mm²
Tensile Strength of Stud	f_u	= **460** N/mm²

1.6 Loads and Combinations

1.6.1 Construction Stage

1.6.1.1 Loads

Load No	Description	Load Case	Load Type	Start Intensity	End Intensity	Start Location (m)	End Location (m)
L1	Ponding	Dead	UN-Area	0.5 kN/m²		Uniform	
L2	Construction	Live	UN-Area	1 kN/m²		Uniform	

1.6.1.2 Service Combinations

No	Combination
SLS1	Dead
SLS2	Dead + Live

1.6.1.3 Ultimate Combinations

No	Combination
ULS1	1.4Dead
ULS2	1.2Dead + 1.6Live

1.6.2 Final Stage

1.6.2.1 Loads

Load No	Description	Load Case	Load Type	Start Intensity	End Intensity	Start Location (m)	End Location (m)
L1	Floor Finish	Dead	UN-Area	2 kN/m²		Uniform	
L2	Live	Live	UN-Area	5 kN/m²		Uniform	

1.6.2.2 Service Combinations

No	Combination
SLS1	Dead
SLS2	Dead + Live
*SLS3	Dead + 0.75Live
** Checked for long term deflection*	

1.6.2.3 Ultimate Combinations

No	Combination
ULS1	1.4Dead

No	Combination
ULS2	1.2Dead + 1.6Live

2.0 OUTPUT REF: ANSI/AISC 360-05 (*ACI 318-19)

2.1 Selfweight Calculations

Steel Beam selfweight M = **0.243** kN/m

Average Concrete Thickness for Selfweight

ED_s = $((T_{rw} + C_{rw})/2.0 * t) / T_{rs} + (D_s - t)$ = **95.1** mm

Selfweight including Concrete and Deck Sheet - Construction Stage

S_{wc} = $M + b * (W_d + w_{cw} * ED_s)$ = **6.563** kN/m

Selfweight including Concrete and Deck Sheet - Final Stage

S_{wf} = $M + b * (W_d + w_{cd} * ED_s)$ = **6.33** kN/m

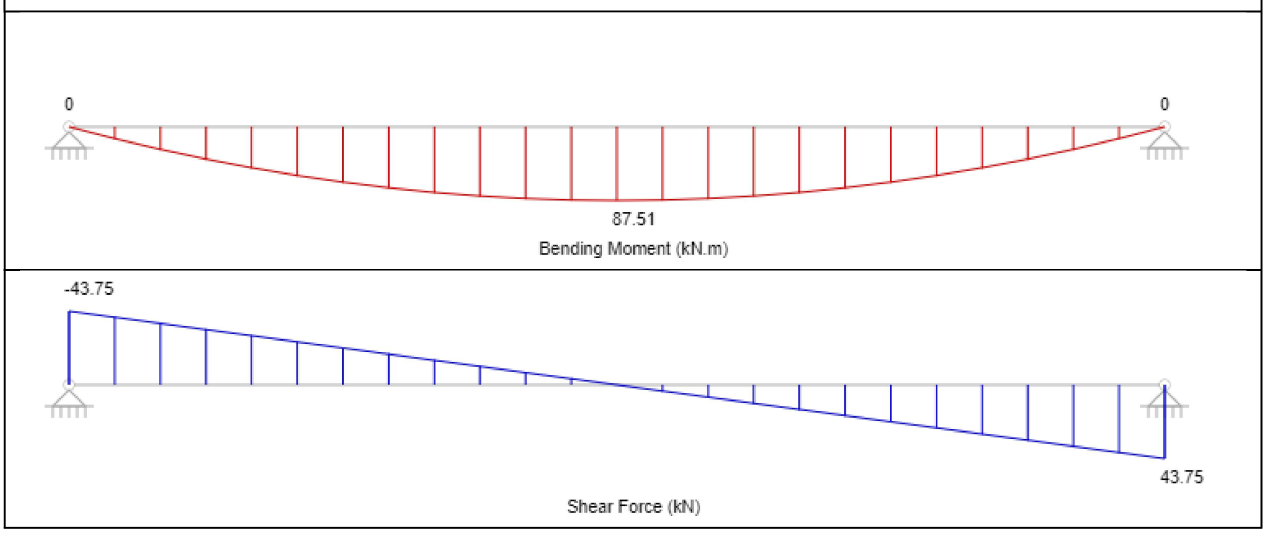
Note: *The selfweight is added to the 'Dead' load cases.*

2.2 Beam Analysis and Design Forces

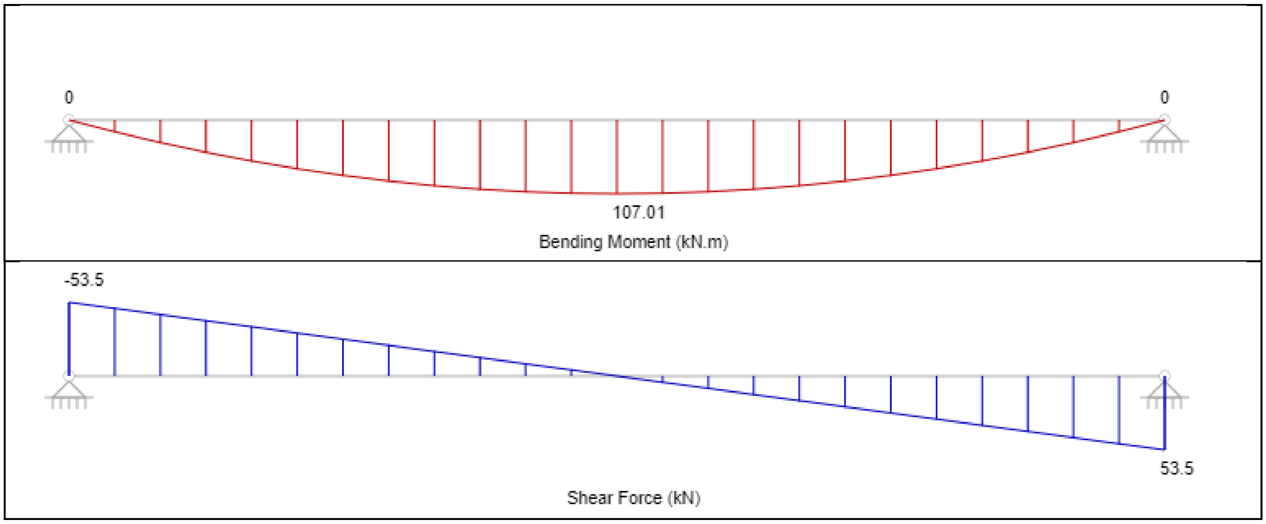
Beam analysis is carried out using stiffness matrix method for the applied loads and its combinations.

2.2.1 Beam Analysis at Construction Stage

Construction Stage ULS1: 1.4Dead

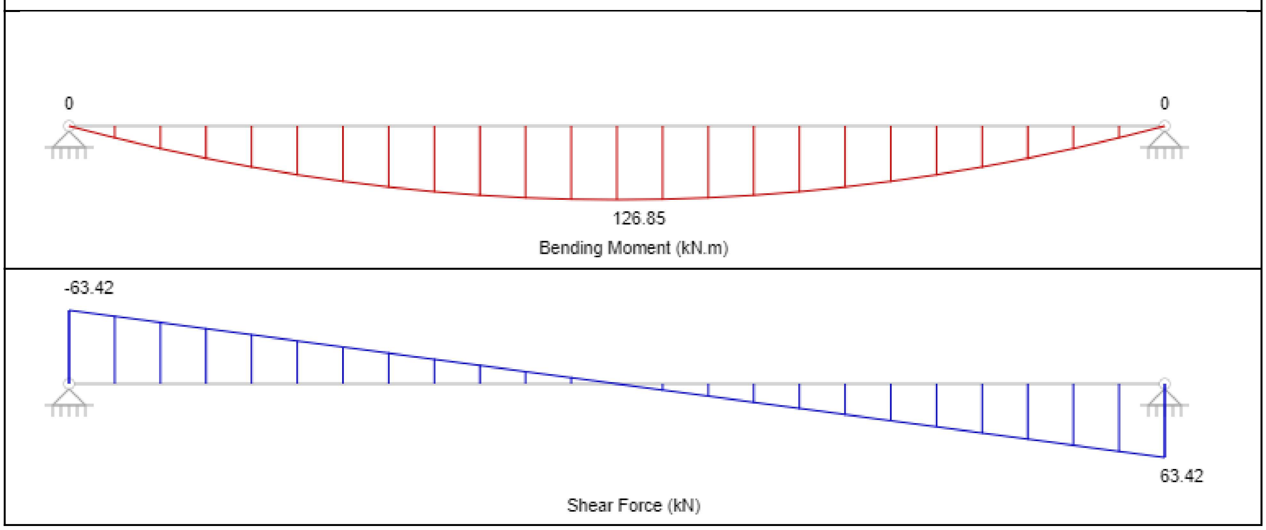


Construction Stage ULS2: 1.2Dead + 1.6Live

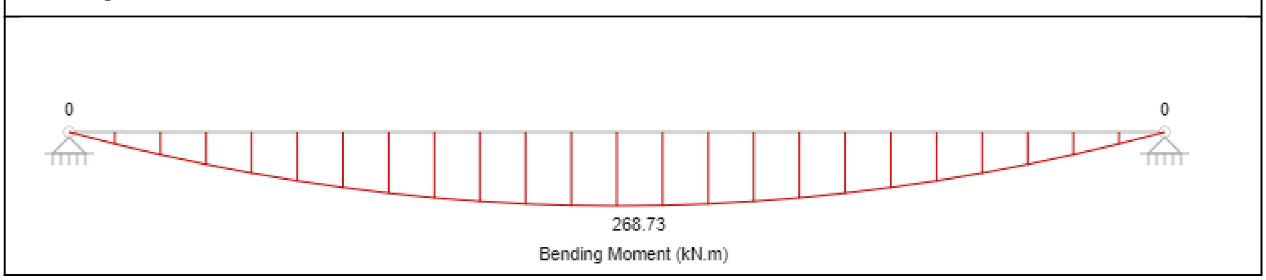


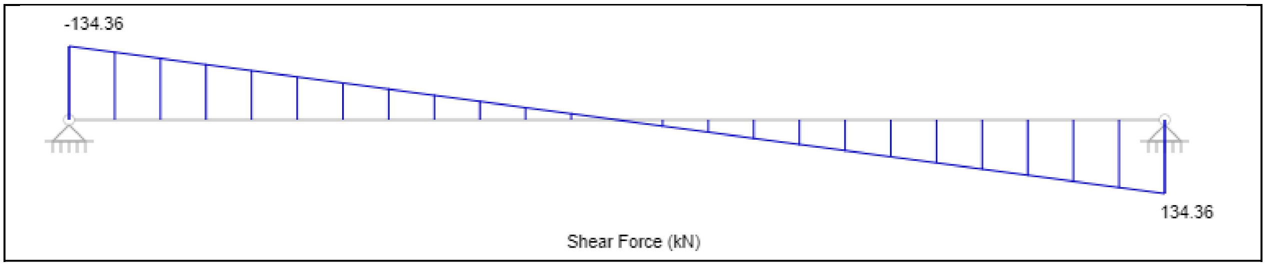
2.2.2 Beam Analysis at Final Stage

Final Stage: ULS1: 1.4Dead



Final Stage: ULS2: 1.2Dead + 1.6Live





2.3 Section Classification

2.3.1 Steel Section Table Properties

UB 305x102x25

Mass **A** (kN/m)	Area **A** (mm^2)	Depth **d** (mm)	Web Thick $\mathbf{t_w}$ (mm)	Flange Thick $\mathbf{t_f}$ (mm)	Flange Width $\mathbf{b_f}$ (mm)	Root radius **r** (mm)	Web depth **h** (mm)
0.24	3160	305.1	5.8	7	101.6	7.6	275.9

Moment Inertia (mm^4)		Plastic Modulus (mm^3)		Elastic Modulus (mm^3)		Torsional Constant	Warping Constant
$\mathbf{I_x}$	$\mathbf{I_y}$	$\mathbf{Z_x}$	$\mathbf{Z_y}$	$\mathbf{S_x}$	$\mathbf{S_y}$	**J** (mm^4)	$\mathbf{C_w}$ (mm^6)
4.46×10^7	1.23×10^6	3.42×10^5	38800.0	2.92×10^5	24200.0	47700.0	2.7×10^{10}

2.3.2 Steel Beam Section Classification

Elastic Modulus of Steel — E = **2.0×10^5** N/mm^2

Flange Width to thickness ratio — λ_f = B / (2 * T) = **7.26**

- Limiting ratio for Compact Section — λ_{pf} = $0.38 * \sqrt{E_s / F_y}$ = **10.79** — Table B4.1

- Limiting ratio for Non-Compact Section — λ_{rf} = $\sqrt{E_s / F_y}$ = **28.4** (Flange is Compact)

Web Depth to thickness ratio — λ_w = h / t_w = **47.57**

- Limiting ratio for Compact Section — λ_{pw} = $3.76 * \sqrt{E_s / F_y}$ = **106.78**

- Limiting ratio for Non-Compact Section — λ_{rw} = $5.7 * \sqrt{E_s / F_y}$ = **161.87** (Web is Compact)

2.4 Construction Stage (Precomposite) Design

2.4.1 Strength Check for flexure

Plastic Moment for Steel Section — M_p = $F_y * Z_x$ = **84.8** kN.m — (F2-1)

Nominal Strength for Compact Flange — M_{nf} = M_p = **84.8** kN.m — (F3-1)

2.4.2 Lateral Buckling Resistance

Buckling Length as defined — L_b = **2.67** m [Restraint At Secondary]

Limiting length for Yielding — L_p = $1.76 r_y \sqrt{\frac{E}{F_y}}$ = **0.99** m — (F2-5)

Shape factor for I section — c = **1.0** — (F2-8a)

Distance between flange centroids — h_o = $d - t_f$ = **293.0** mm — (F2-6)

Effective radius of gyration — r_{ts} = **25.0** mm { $r_{ts}^2 = \frac{\sqrt{I_y C_w}}{S_x}$ } — (F2-7)

Limiting length for inelastic buckling — L_r = $1.95 r_{ts} \frac{E}{0.7F_y} \sqrt{\frac{Jc}{S_x h_o}} \sqrt{1 + \sqrt{1 + 6.76 \left(\frac{0.7 F_y S_x h_o}{EJc} \right)^2}}$ — (F2-6)

= **3.01** m

Unbraced (m)	Unbraced Segment Moments (kN.m)				C_b	M_{nl} * (kN.m)	M_n ** (kN.m)	$M_d = \phi_b M_n$ (kN.m)	Uratio M_{max} / M_d
	M_A	M_B	M_C	M_{max}					
1.4Dead									
0.0 - 2.67	26.7	48.6	65.6	77.8	1.46	82.3	82.3	74.1	1.05
2.67 - 5.34	86.0	87.2	83.6	87.5	1.02	57.3	57.3	51.6	1.697
5.34 - 8.01	61.7	43.5	20.4	72.3	1.5	84.8	84.8	76.3	0.947
1.2Dead + 1.6Live									
0.0 - 2.67	32.7	59.4	80.3	95.1	1.46	82.3	82.3	74.1	1.284
2.67 - 5.34	105.2	106.6	102.2	107.0	1.02	57.3	57.3	51.6	2.075
5.34 - 8.01	75.4	53.1	24.9	88.4	1.5	84.8	84.8	76.3	1.158

$C_b = \frac{12.5M_{max}}{2.5M_{max} + 3M_A + 4M_B + 3M_C} R_m \leq 3.0$ {R_m = 1.0 for double symmetry section} (F1-1)

* $M_{nl} = C_b \left[M_p - (M_p - 0.7F_y S_x) \left(\frac{L_b - L_p}{L_r - L_p} \right) \right] \leq M_p$ since $L_p < L_b \leq L_r$ (F2-2)

** $M_n = \min(M_{nf}, M_{nl})$ F3 (1)

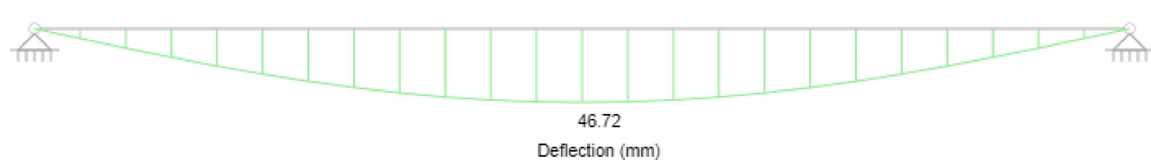
2.4.3 Strength Check for Shear

Web Area	A_w	= d * t_w = **1769.6** mm²
Web Shear Coefficient	C_v	= **1.0** { since $\lambda_w = h/t_w \leq 2.24 * \sqrt{\frac{E}{F_y}}$ = 63.61 } (G2-2)
Nominal Shear Strength	V_n	= 0.6 * F_y * A_w * C_v = **263.3** kN (G2-1)
Available Shear Strength	$\phi_v V_n$	= **263.3** kN {ϕ_v = 1.0}
Maximum Design Shear force from analysis	V_{max}	= **53.5** kN (Comb: ULS 2)
Design Ratio	U_{ratio}	= **0.203**

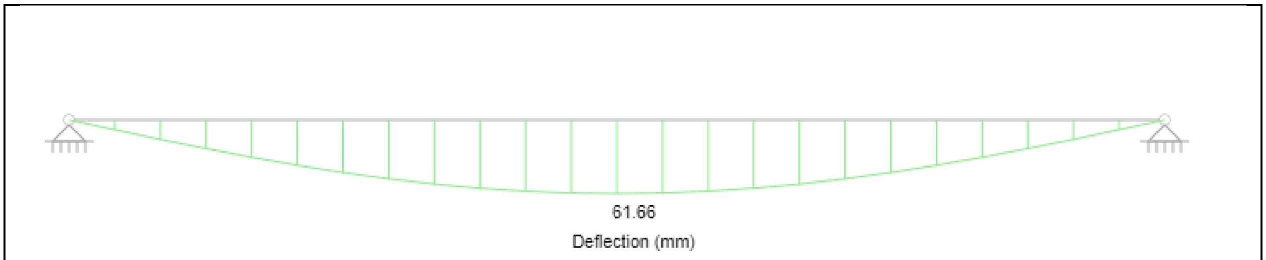
2.4.4 Deflection Check

Beam analysis is carried out using stiffness matrix method for the load combinations at service stage. The moment of inertia is I_x of the steel section is used for the deflection calculation.

Construction Stage SLS1: Dead



Construction Stage SLS2: Dead + Live



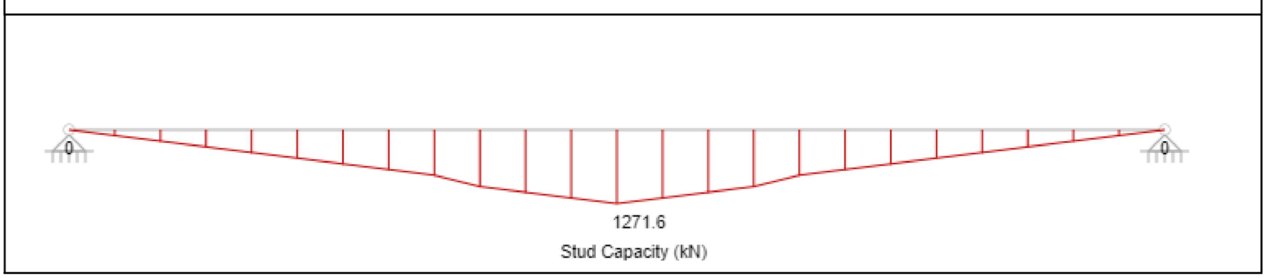
Deflection	$\Delta_{Allowable}$ (mm)	Δ_{actual} (mm)	Ratio	Status
SLS 1	**22.2** (L/360)	**46.7** (L/171.2)	**2.102**	**Fail**
SLS 2	**30.8** (L/260)	**61.7** (L/129.7)	**2.004**	**Fail**

2.5 Final Stage (Composite) Design

2.5.1 Elastic Properties of Composite Section

Effective Width	b_{eff}	= Min(b, L/4) = **2000.0** mm
Top Slab Thickness	t_c	= D_s - t = **70.0** mm
Concrete Area of the Top slab	C_{as}	= b_{eff} * t_c = **140000.0** mm²
Average Width of the Metal Deck Rib	W_{ar}	= (T_{rw} + + C_{rw}) / 2 = **125.5** mm
Total Width of the Metal Deck Rib	T_{wr}	= (W_{ar} / T_{rs}) * b_{eff} = **836.7** mm
Concrete Area within Metal Ribs	C_{ar}	= T_{wr} * t = **50200.0** mm²
Total Concrete Sectional Area	C_{at}	= C_{as} + C_{ar} = **190200.0** mm²
Total Compression in Concrete	F_{cc}	= C_{at} * 0.85 * f_{cu} = **4850.1** kN
Total Tension in Steel	F_{ts}	= A_s * F_y = **783.7** kN
Critical Resistance	C_{rr}	= Min (F_{cc}, F_{ts}) = **783.7** kN
---Stud Capacity Calculation Upto Mid Span---		
Stud Area	A_s	= $\pi * S_d^2 / 4$ = **283.5** mm²
Midspan Studs Count Upto Center	N_{ms}	= **13**
Deck Orientation Factor (Longitudinal)	R_p	= **0.75**
Midspan Stud Group Factor	R_g	= **1.0**
	Q_1	= $0.5 * A_s * \sqrt{(f_{cu} * E_c)}$ = **124.6** kN
	Q_2	= $R_g * R_p * A_s * f_u$ = **97.8** kN
	Q_n	= Min(Q_1, Q_2) = **97.8** kN
Stud Capacity Upto Midspan	S_{cm}	= $N_s * N_{ms} * Q_n$ = **1271.6** kN

Stud Capacity along Span

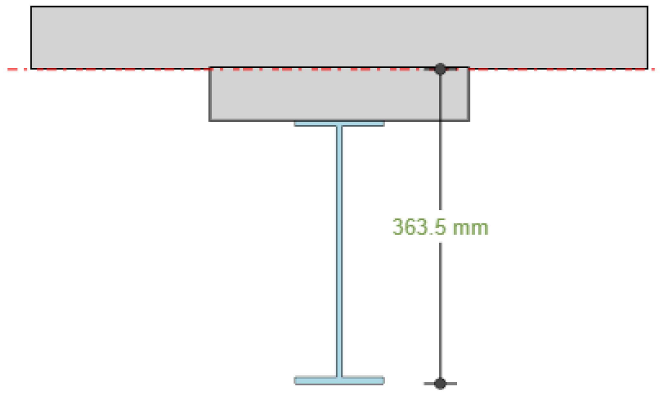


---Short Term---

Modulus of Concrete E_c = $4700 * \sqrt{f_{cu}}$ = **25743.0** N/mm² *Eq.19.2.2.1

Steel Concrete Modular Ratio	m	= E_s / E_c = **7.77**	
Elastic Neutral Axis from Bottom	ENA	= **363.49** mm { By Iteration }	
Transformed Moment of Inertia	I_{tr}	= **2.188 x 10^8** mm^4	
Effective Moment of Inertia	I_{eff}	= $0.75 (I_x + \sqrt{(Min(S_{cm,C}) / C_{rr}) * (I_{tr} - I_x)})$	C-13-3
		= **1.641 x 10^8** mm^4	

The concrete portion if any below the neutral axis is ignored for property calculation.



---Long Term---

Modulus of Concrete	E_{cl}	= $(1 - LR_{ec}/100) * E_c$ = **12871.5** N/mm²	
Steel Concrete Modular Ratio	ml	= E_s / E_{cl} = **15.54**	
Elastic Neutral Axis from Bottom	ENAl	= **338.1** mm { By Iteration }	
Transformed Moment of Inertia	I_{trl}	= **1.998 x 10^8** mm^4	
Effective Moment of Inertia	I_{effl}	= $0.75 (I_x + \sqrt{(Min(S_{cm,C}) / C_{rr}) * (I_{trl} - I_x)})$	C-13-3
		= **1.498 x 10^8** mm^4	

2.5.2 Plastic Properties of Composite Section

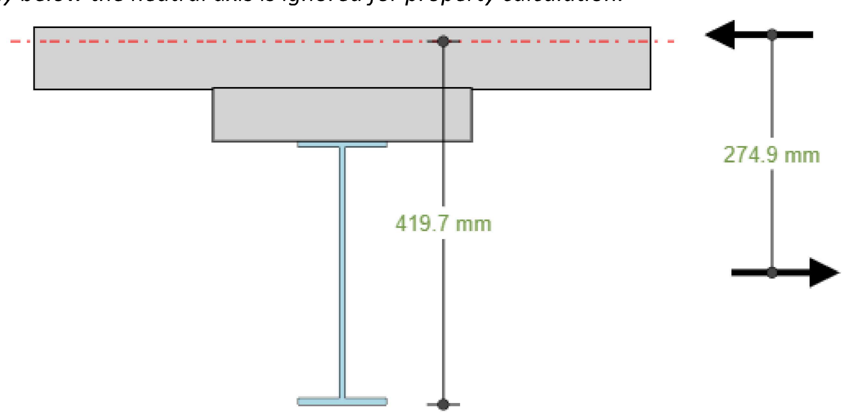
Note: Plastic properties varies along the span due to the variation of stud capacity along the span. The calculation is presented for the plastic property at mid span.

Plastic Neutral Axis	PNA	= **419.7** mm {By iteration}
Concrete Plastic Compression	P_c	= **783.7** kN

Since the compression on the concrete side (Limited by the Stud Capacity) is more than the Tension Capacity of the Steel Section, the plastic neutral axis is inside the concrete section.

Steel Plastic Tension	P_t	= **783.7** kN
Leverarm Between Compression and Tension	L_r	= **274.9** mm
Plastic Moment Capacity	M_{np}	= $P_c * L_r$ = **215.4** kN.m

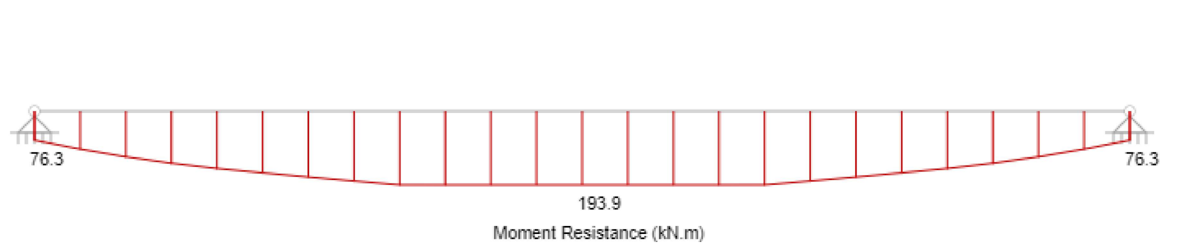
The concrete portion if any below the neutral axis is ignored for property calculation.



2.5.2.1 Strength Check for Flexure

Available Moment Resistance $\phi_b M_{np}$ = **193.9** kN.m {ϕ_b = 0.9}

Moment Resistance along Span according to the distribution of studs



Critical Total Moment from Analysis	M_c	= **268.7** kN.m { Comb: ULS 2 @ 4.0 m }
Selfweight Moment Component	M_{c1}	= **60.7** kN.m
Moment Component (Without Selfweight)	M_{c2}	= **208.0** kN.m
Moment Resistance (PreComposite)	M_{r1}	= ϕM_{nf} = **76.3** kN.m
Moment Resistance at critical point (PostComposite)	M_{r2}	= **193.9** kN.m
Design Ratio		= $M_{c1} / M_{r1} + M_{c2} / M_{r2}$ = **1.868**

Note: *The critical moment is not necessarily the maximum moment. It depends on the moment/capacity ratio along the span. The capacity varies according to the distribution of the studs.*

2.5.2.2 Strength Check for Shear

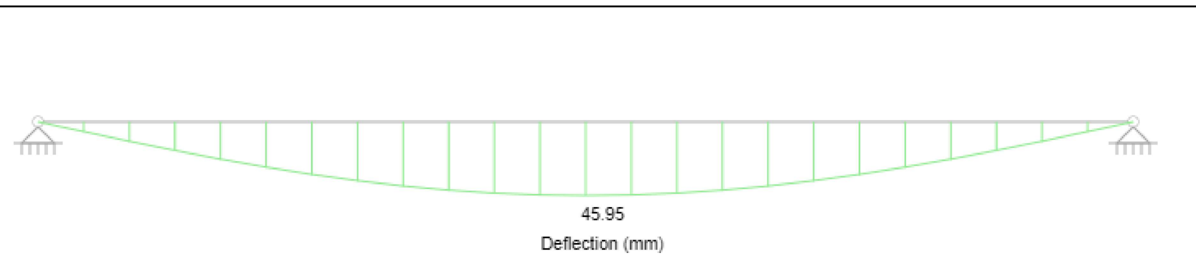
Note: *Concrete portion is not considered to contribute to the shear strength.*

Available Shear Strength	$\phi_v V_n$	= **263.3** kN {Same as Construction stage}
Maximum Design Shear force from analysis	V_{max}	= **134.4** kN (Comb: ULS 2)
Design Ratio	U_{ratio}	= **0.51**

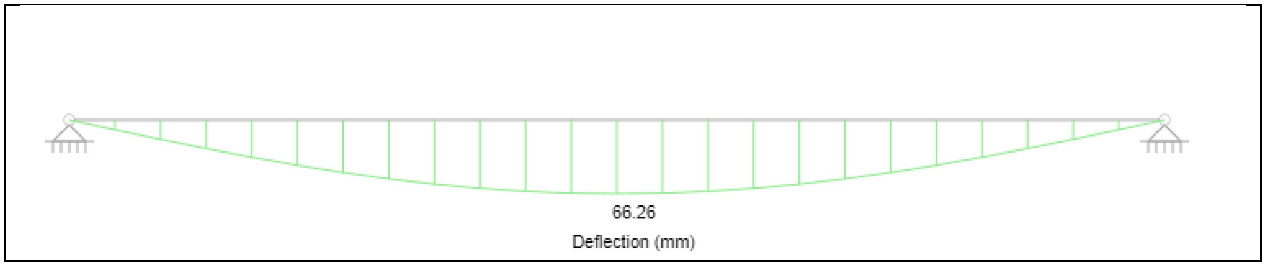
2.5.3 Deflection Check

Beam analysis is carried out using stiffness matrix method for the load combinations at service stage. The moment of inertia is I_{eff} for short term deflection and the moment of inertia is I_{effl} for long term deflection calculation. The moment of Inertia I_x of the steel section is used for the selfweight (Deflection prior to composite action).

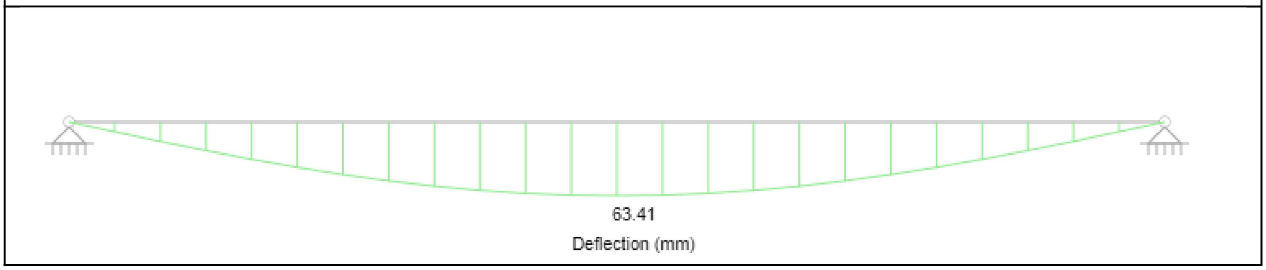
Final Stage SLS1: Dead



Final Stage SLS2: Dead + Live



Final Stage SLS3*: Dead + 0.75Live {**Long Term**}



Deflection	$\Delta_{Allowable}$ (mm)	Δ_{actual} (mm)	Ratio	Status
SLS 1	**22.2** (L/360)	**45.9** (L/174.1)	**2.068**	**Fail**
SLS 2	**30.8** (L/260)	**66.3** (L/120.7)	**2.153**	**Fail**
SLS 3* {Long Term}	**30.8** (L/260)	**63.4** (L/126.2)	**2.061**	**Fail**

3.0 SUMMARY

3.1 Section Classification

Description	λ	λp	λr	Result	Status
Flange	7.26	10.79	28.4	**Compact**	**Pass**
Web	47.57	106.78	161.87	**Compact**	**Pass**

Note:

λ Width to thickness ratio

λ_p Limiting width to thickness ratio for Compact section

λ_r Limiting width to thickness ratio for Non-Compact section

3.2 Construction Stage (Precomposite)

3.2.1 Construction Stage Design check

	Load Combination	Allowable	Actual	Status
Moment (kN.m)	ULS 2	**74.1**	**107.0**	**Fail**
Shear (kN)	ULS 2	**263.3**	**53.5**	**Pass**
Deflection (mm)	SLS 1	**22.2** (L/360)	**46.7** (L/171.2)	**Fail**

3.3 Final Stage (Composite) design check

3.3.1 Composite Components Capacities

Components	Capacity (kN)
Total Concrete Compression	**4850.1**
Cumulative Stud Capacity upto Center	**1271.6**
Steel Section	**783.7**

3.3.2 Final Stage Design Check

	Combination	Allowable	Actual	Status
Moment due to selfweight (kN.m)	ULS 2	**76.3**	**60.7**	**Pass**
Moment without selfweight (kN.m)	ULS 2	**193.9**	**208.0**	**Pass**
Moment Interaction Ratio	ULS 2	**1.0**	**1.868**	**Fail**
Shear (kN)	ULS 2	**263.3**	**134.4**	**Pass**
Deflection (mm)	SLS 2	**30.8** (L/260)	**66.3** (L/120.7)	**Fail**