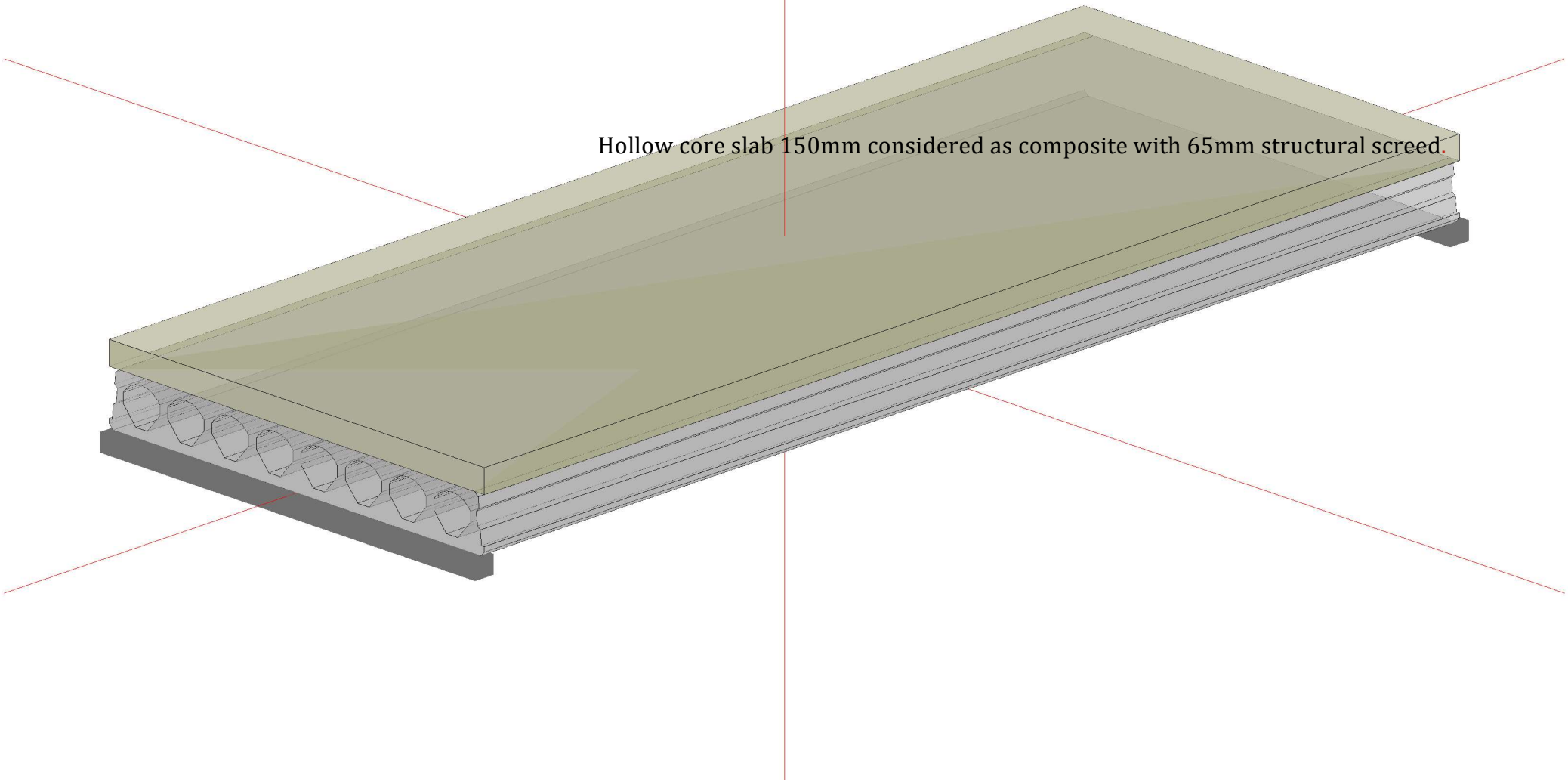
Project: BUID Dissertation - Composite action of Hollow Core slab
Problem: HCS 150 Composite

Appendix - Concise Beam Software Analysis Results



Hollow core slab 150mm considered as composite with 65mm structural screed.

Project: BUID Dissertation - Composite action of Hollow Core slab
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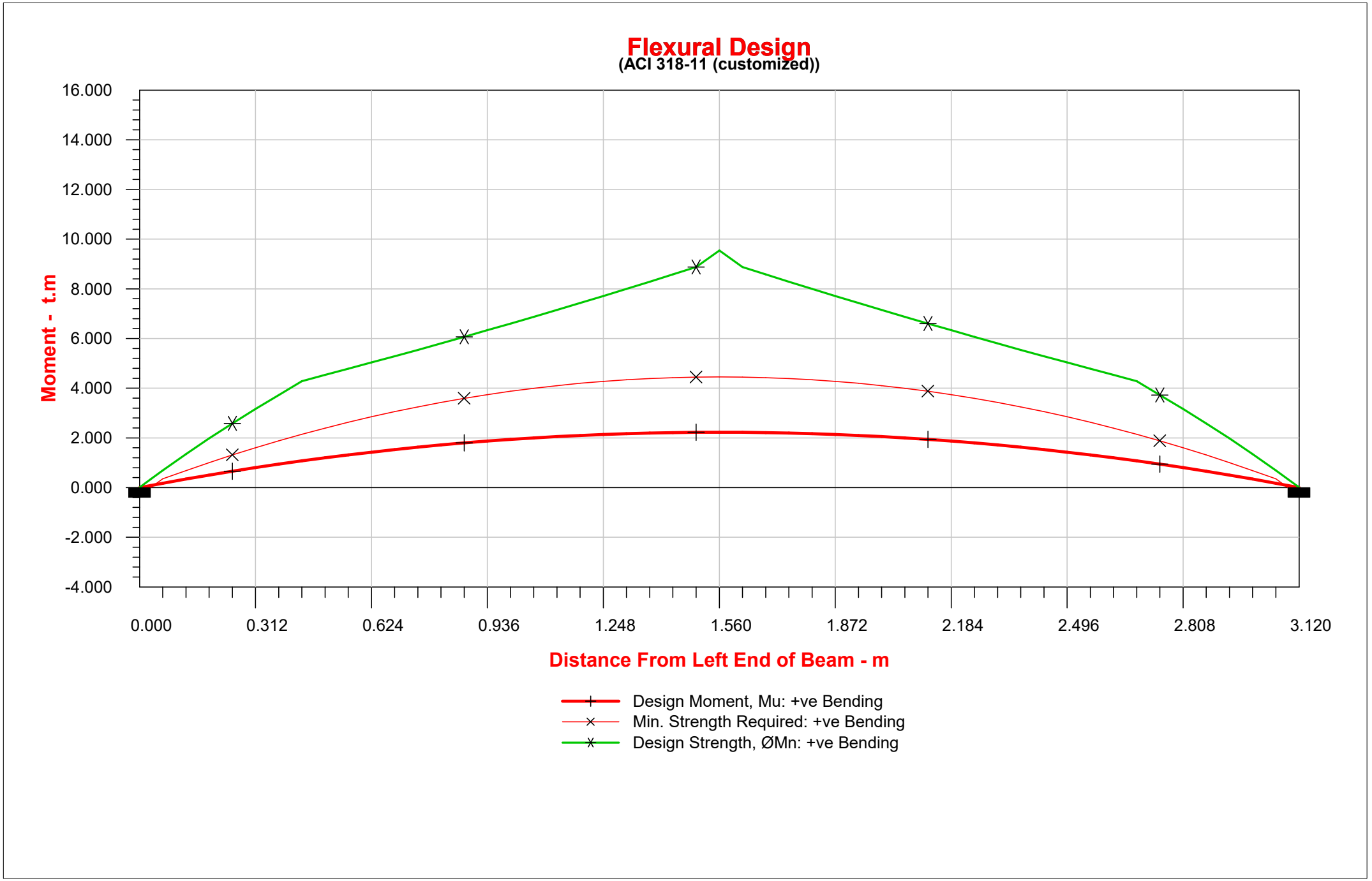

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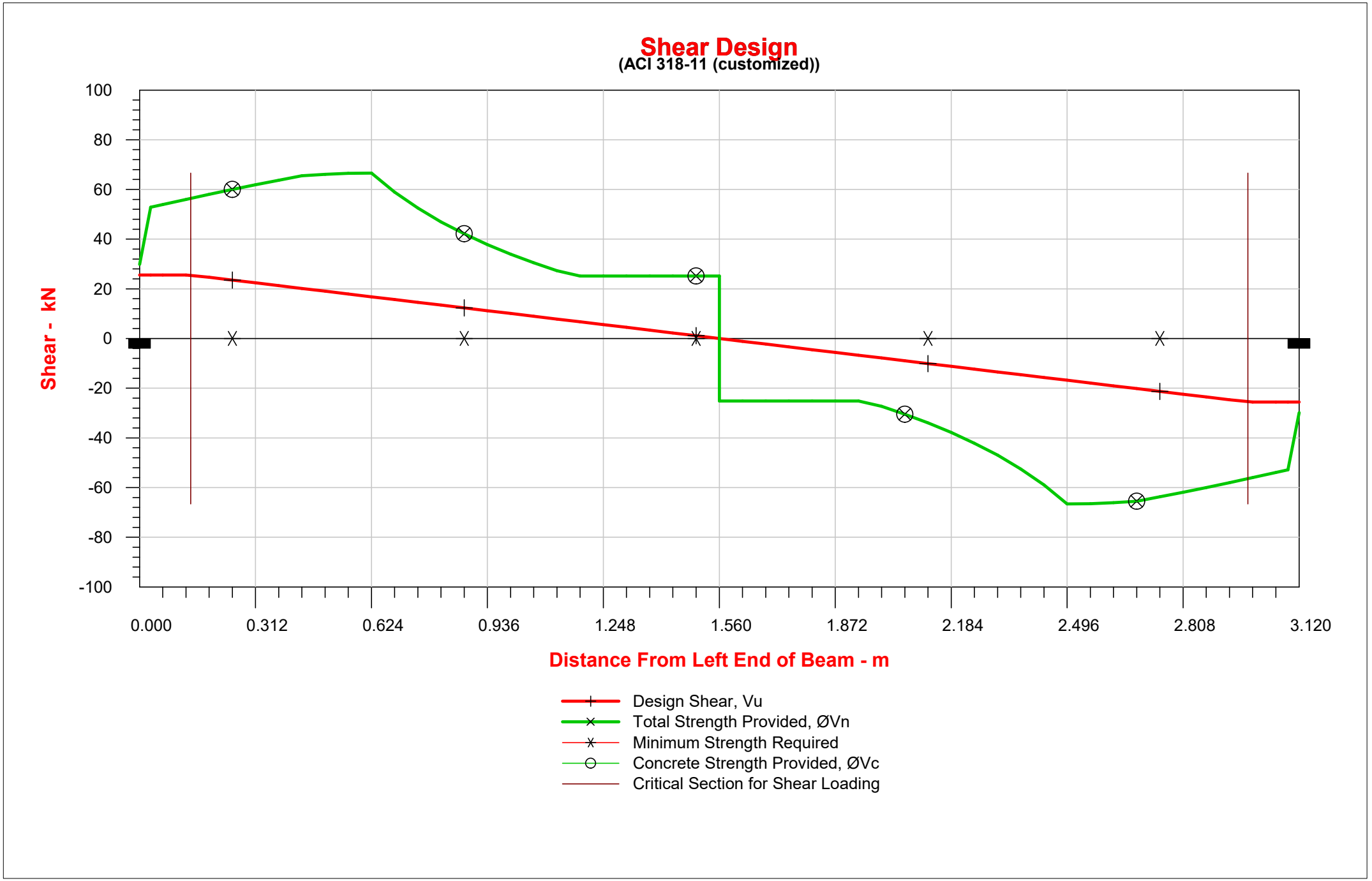

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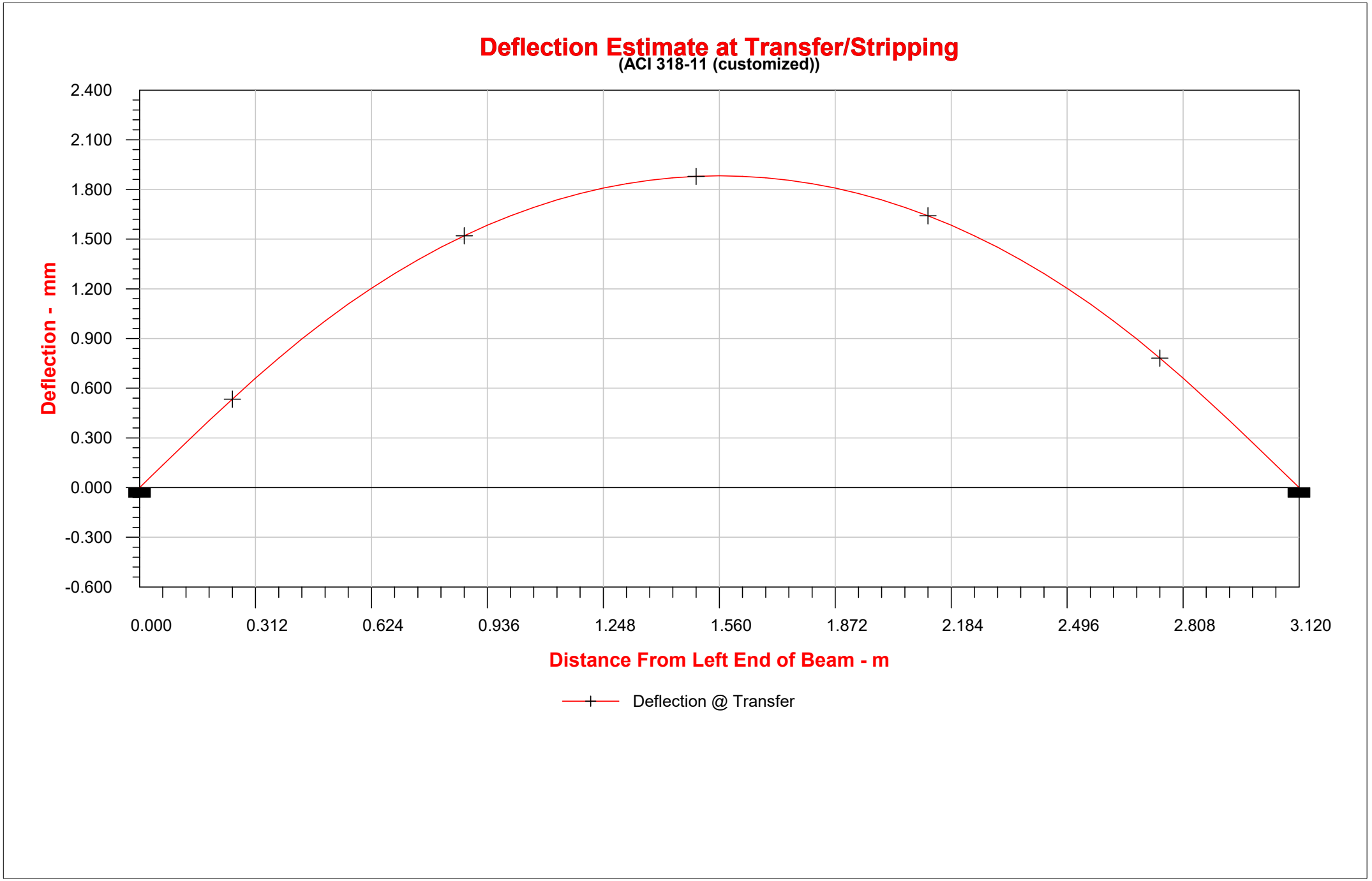

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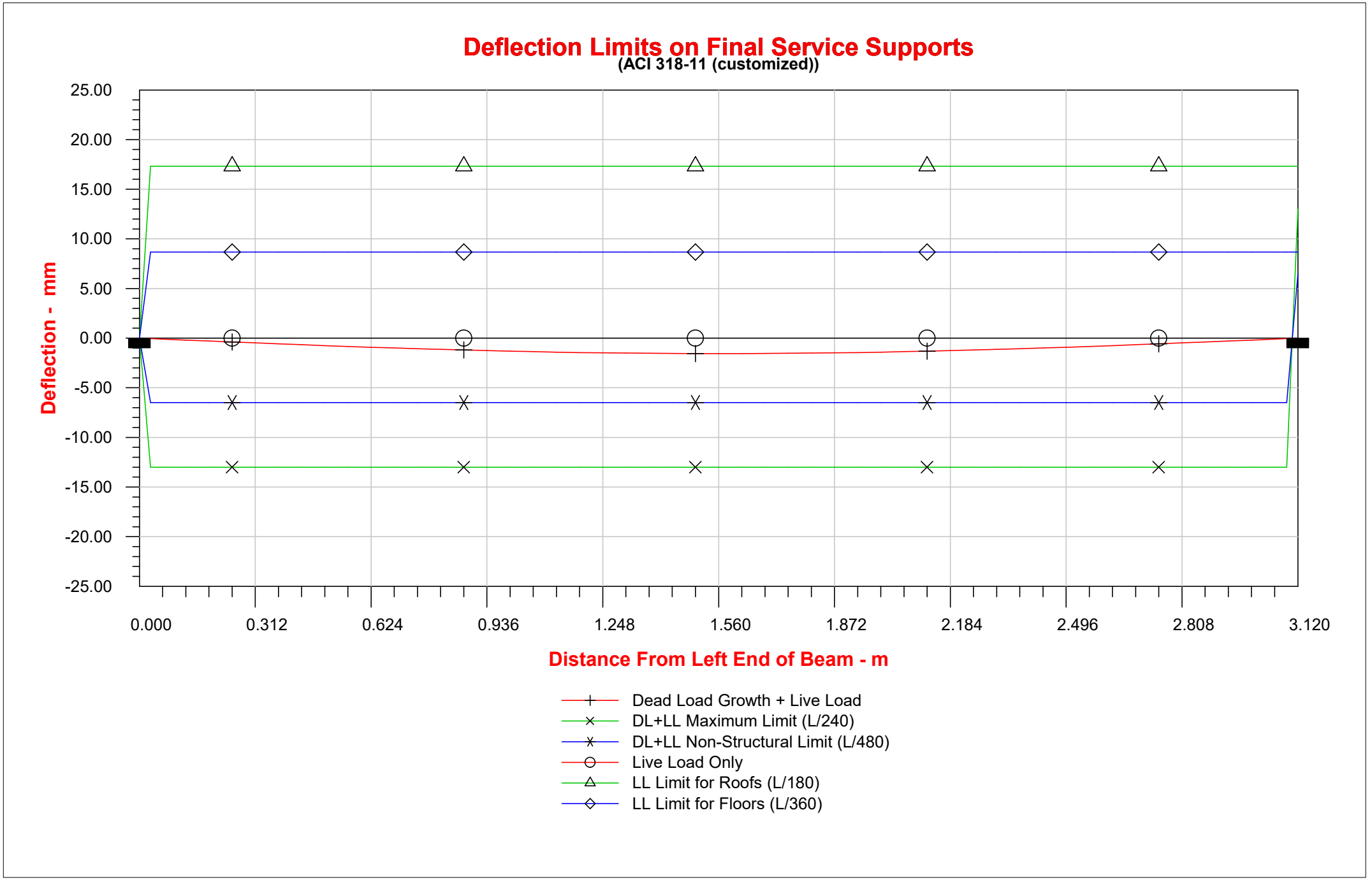

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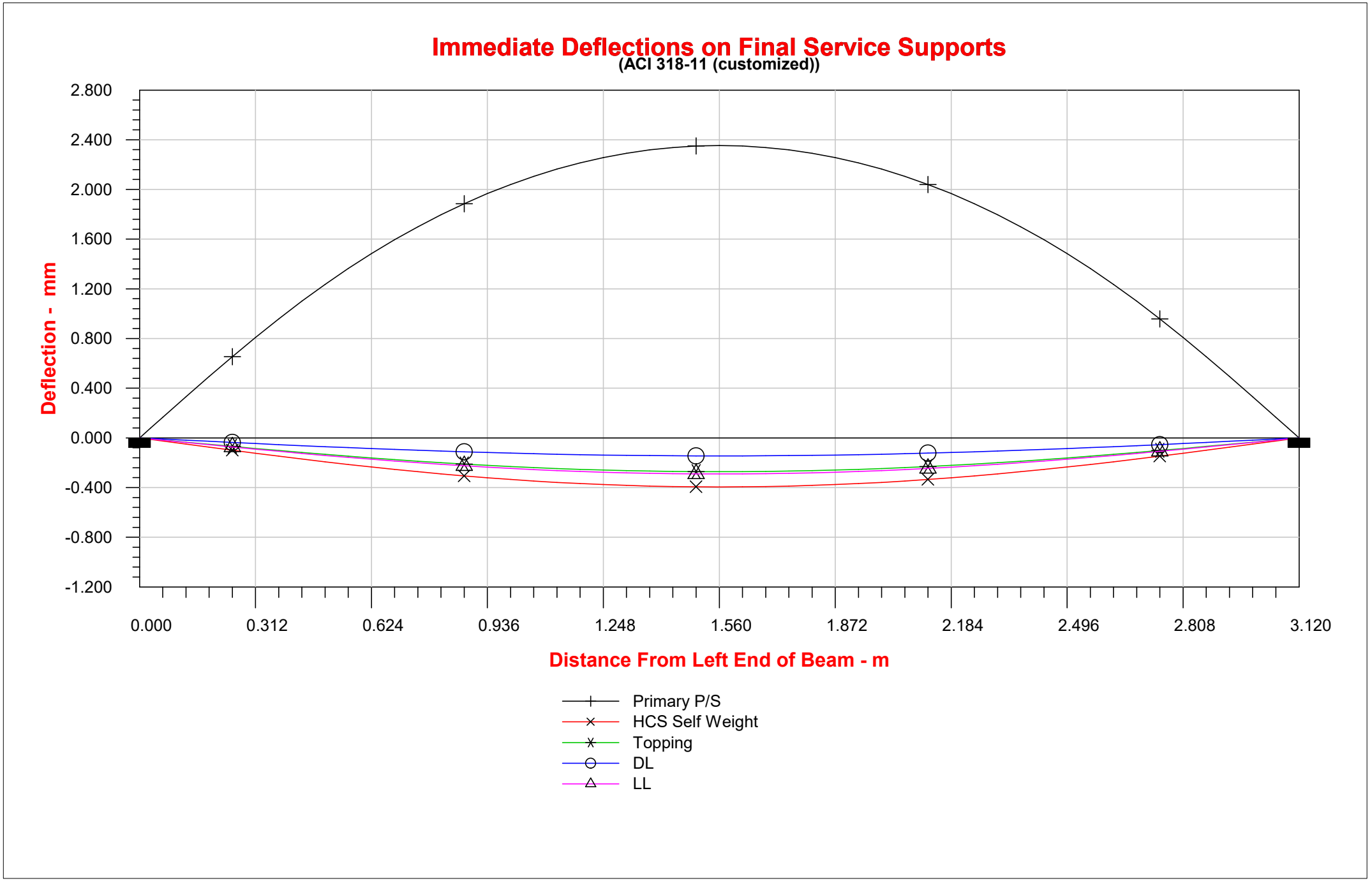
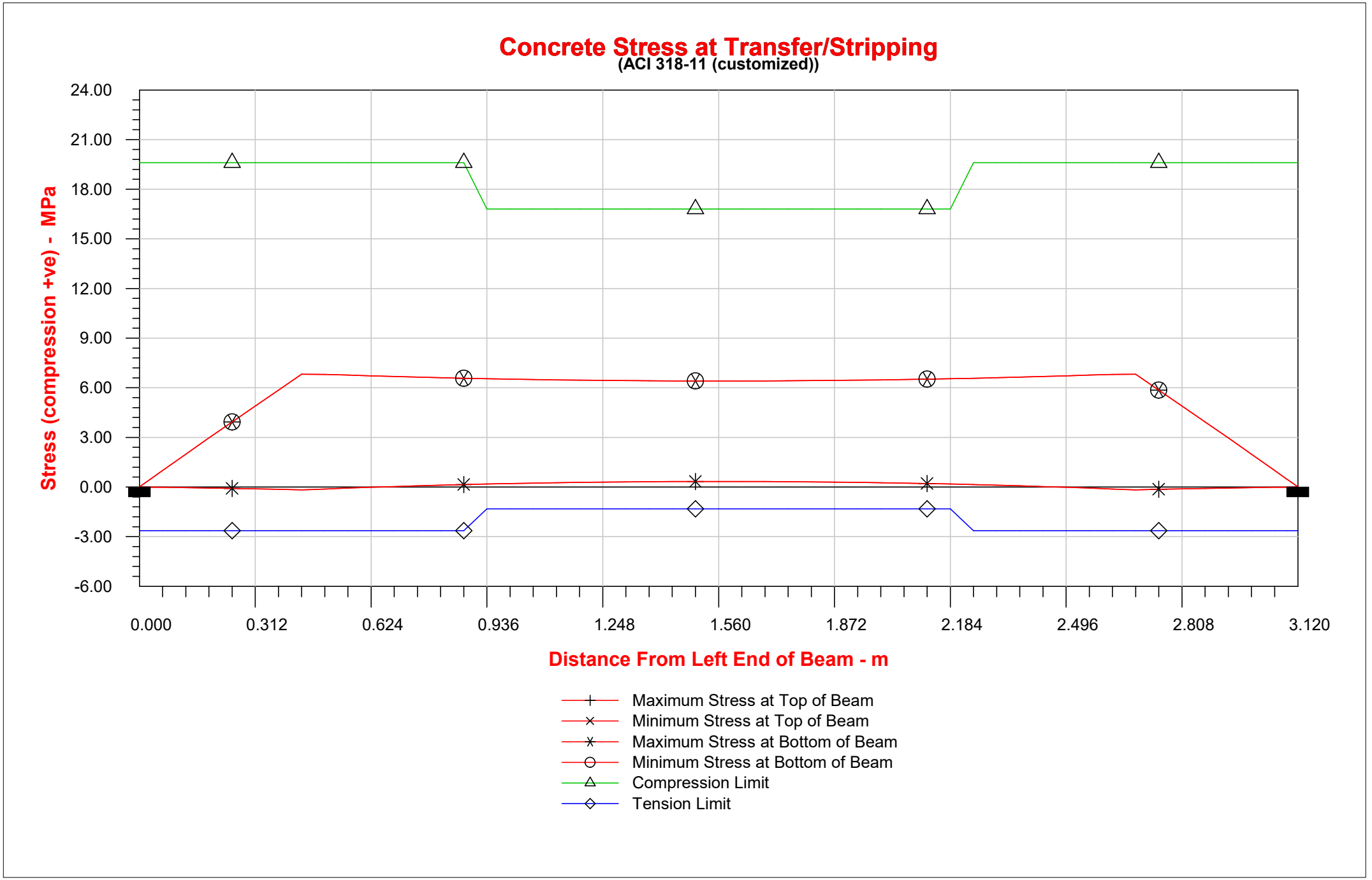
Problem: HCS 150 Composite



Project: BUID Dissertation - Composite action of Hollow Core slab
Problem: HCS 150 Composite



Project: BUID Dissertation - Composite action of Hollow Core slab
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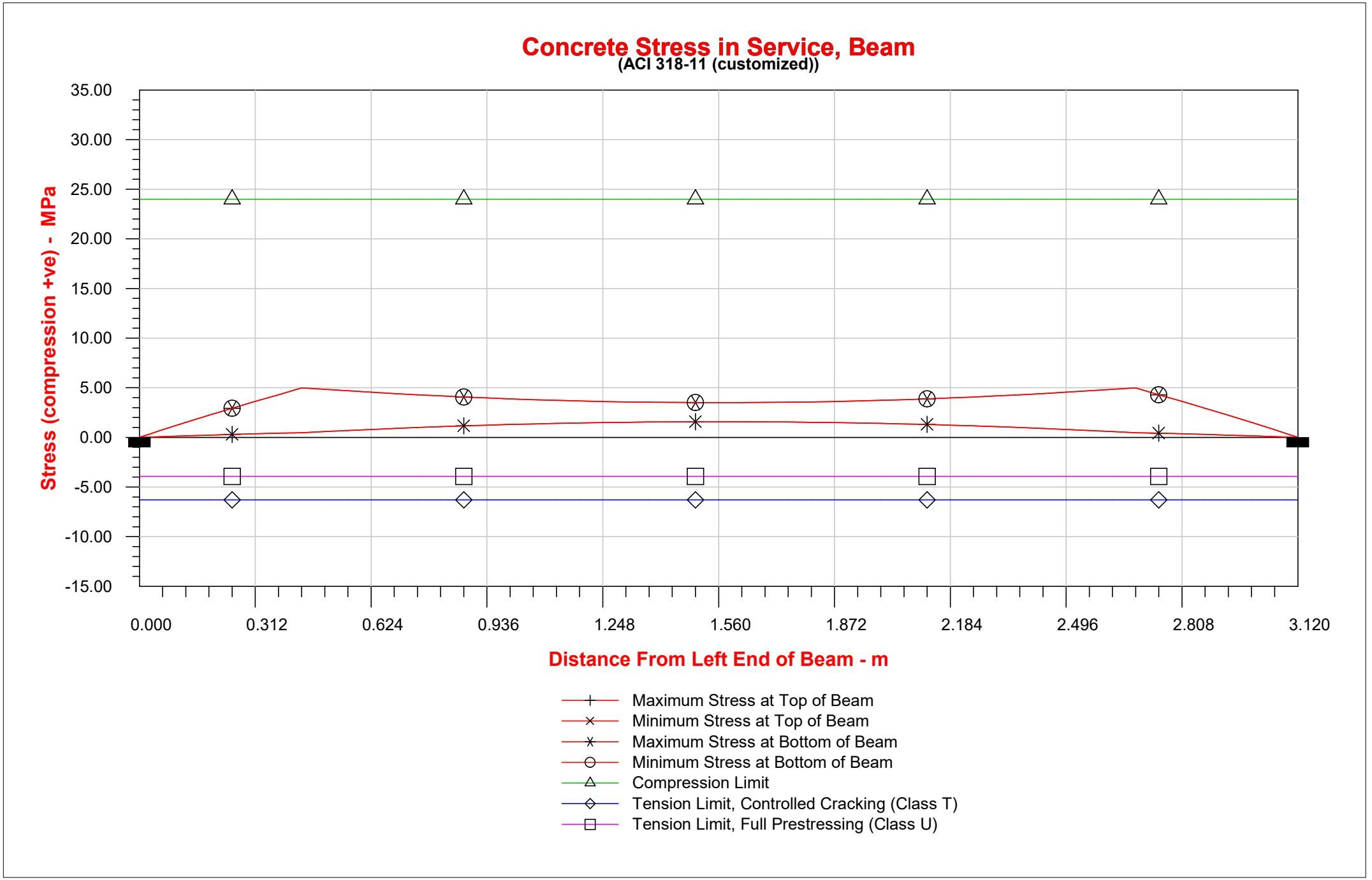

Project: BUID Dissertation - Composite action of Hollow Core slab
Problem: HCS 150 Composite

SUMMARY REPORT

Design Code Used: ACI 318-11 (customized)

NON-DEFAULT OPTION SETTINGS

** OFF ** G2: Use PCI Standard Design Practice, TR-7-05 (ACI codes only)
** ON ** P1: Vary user defined losses along beam
** OFF ** F7: Reduce ϕ in the development length of strands (CSA A23.3 only)
** OFF ** F8: Use a rectangular stress block at concrete ultimate strain
** ON ** S10: Use the ultimate section capacity for horizontal shear (moment region check)
** OFF ** D3: Have Concise Beam calculate the long-term deflection multipliers for prestressed Beams

---

CONCRETE MATERIAL PROPERTIES

	Precast Beam			Cast-in-Place Pour		
Concrete Density	Wt	=	2400 kg/m^3	Wt	=	2400 kg/m^3
Compressive Strength	f'c	=	40.0 MPa	f'c	=	28.0 MPa
Modulus of Elasticity	Ec	=	31783 MPa	Ec	=	26591 MPa
Strength at Transfer	f'c	=	28.0 MPa			
Modulus of Elast. at Transfer	Ec	=	26591 MPa			
Strength at Lifting	f'c	=	30.0 MPa			
Modulus of Elast. at Lifting	Ec	=	26621 MPa			

Cement Content = 410 kg/m^3
Air Content = 5.00 %
Slump = 50.0 mm
Aggregate Mix = 0.40 (fine to total aggregate ratio)
Aggregate Size = 20.0 mm
Basic Shrinkage Strain = 780.000E-6

Construction Schedule
Age at Transfer = 0.75 days
Age at Erection = 40 days
Age at Cast-in-Place Pour = 50 days
Age Cast-in-Place is Composite = 53 days
Age Construction is Complete = 143 days

Curing Method = Moist
Relative Humidity in Service = 70 %
Ambient Temperature in Service = 20 deg C

PRECAST BEAM LAYOUT

Segment/Length			Section Identification			Offset	
No	From m	To m	Length m	Folder Name	Section Name	Section Type	Z mm	Y mm
1	0.000	3.120	3.120	Standard HC	HCS150	Hollowcore	0.0	0.0

CAST-IN-PLACE POUR LAYOUT

Segment/Length			Slab/Topping Parameters			Haunch Paramaters			Vertical	Composite Interface		Total Width	
No	From m	To m	Length m	Thick. mm	Width mm	Offset mm	Thick. mm	Width mm	Offset mm	Offset mm	Width mm	Offset mm	Actual mm	Effective mm
1	0.000	3.120	3.120	65.0	1200.0	0.0	0.0	0.0	0.0	0.0	1140.2	0.0	1200.0	1200.0

Beam is UNSHORED during the cast-in-place pour and superimposed dead load.

* Long offset from left end of beam. Transverse offset from top of precast to top of opening
for horizontal orientation or from center of precast to center of opening for vertical orientation.

Span Length at Transfer = 3.120 m, Centre of Supports, Left @ 0.000 m, Right @ 3.120 m
Span Length during Lift = 3.120 m, Centre of Supports, Left @ 0.000 m, Right @ 3.120 m Loop Height = 0.0 mm
Span Length in Service = 3.120 m, Centre of Supports, Left @ 0.000 m, Right @ 3.120 m
Total Beam Length = 3.120 m, Bearing Length, Left = 60.0 mm, Right = 60.0 mm

First flexural frequency of beam is approximately 30.54 Hz

GROSS PRECAST SECTION PROPERTIES (NON-COMPOSITE)
(based on Ec of the precast beam - transformed area of rebar and strand NOT included)

Seg. No.	Section Properties			Section Height	Section Width	Shear Width	Volume / Surface	Section Moduli	
	A mm^2	I mm^4	yb mm	mm	mm	mm	mm	Sb mm^3	St mm^3
1	100667	275.353E+6	71.0	150.0	1200.0	213.0	38.00	-3.878E+6	3.485E+6

GROSS COMPOSITE SECTION PROPERTIES
(based on Ec of the precast beam - transformed area of rebar and strand NOT included)

Seg. No.	Section Properties			Section Height	Section Moduli			
	Ac mm^2	Ic mm^4	yb mm	mm	Sb mm^3	St mm^3	Sbc mm^3	Stc mm^3
1	165925	790.549E+6	114.9	215.0	-6.883E+6	22.493E+6	22.493E+6	7.894E+6

Note: Sb & St = bottom and top of the precast beam, Sbc & Stc = bottom and top of the cast-in-place pour.

UNCRACKED SECTION PROPERTIES SUMMARY

	Net Precast Section at Transfer (based on Eci) (include rebar,deduct strand)			Transformed Precast Section at Transfer (based on Eci) (include rebar and strand)			Transformed Precast Section in Service (based on Ec) (include rebar and strand)			Transformed Composite Section in Service (based on Ec) (include rebar and strand)		
x m	A mm^2	I mm^4	yb mm	A mm^2	I mm^4	yb mm	A mm^2	I mm^4	yb mm	Ac mm^2	Ic mm^4	ybc mm
0.000	100338	274.798E+6	71.1	100669	275.356E+6	71.0	100669	275.356E+6	71.0	165927	790.562E+6	114.9
0.250	100338	274.798E+6	71.1	101970	277.515E+6	70.5	101724	277.112E+6	70.6	166982	798.113E+6	114.3
0.562	100338	274.798E+6	71.1	102811	278.882E+6	70.1	102407	278.228E+6	70.3	167665	802.949E+6	114.0
0.874	100338	274.798E+6	71.1	102811	278.882E+6	70.1	102407	278.228E+6	70.3	167665	802.949E+6	114.0
1.186	100338	274.798E+6	71.1	102811	278.882E+6	70.1	102407	278.228E+6	70.3	167665	802.949E+6	114.0

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Problem: HCS 150 Composite

1.498	100338	274.798E+6	71.1	102811	278.882E+6	70.1	102407	278.228E+6	70.3	167665	802.949E+6	114.0
1.560	100338	274.798E+6	71.1	102811	278.882E+6	70.1	102407	278.228E+6	70.3	167665	802.949E+6	114.0
1.622	100338	274.798E+6	71.1	102811	278.882E+6	70.1	102407	278.228E+6	70.3	167665	802.949E+6	114.0
1.810	100338	274.798E+6	71.1	102811	278.882E+6	70.1	102407	278.228E+6	70.3	167665	802.949E+6	114.0
1.934	100338	274.798E+6	71.1	102811	278.882E+6	70.1	102407	278.228E+6	70.3	167665	802.949E+6	114.0
2.246	100338	274.798E+6	71.1	102811	278.882E+6	70.1	102407	278.228E+6	70.3	167665	802.949E+6	114.0
2.558	100338	274.798E+6	71.1	102811	278.882E+6	70.1	102407	278.228E+6	70.3	167665	802.949E+6	114.0
2.870	100338	274.798E+6	71.1	101970	277.515E+6	70.5	101724	277.112E+6	70.6	166982	798.113E+6	114.3
3.120	100338	274.798E+6	71.1	100669	275.356E+6	71.0	100669	275.356E+6	71.0	165927	790.562E+6	114.9

These section properties can used to calculate uncracked concrete stresses using the following guidelines.

Net Precast Section at Transfer properties are used with the initial prestress after transfer (after elastic shortening loss).
Transformed Precast Section at Transfer properties are used with the precast beam self-weight.
Transformed Precast Section in Service properties are used with external loads applied to the non-composite precast beam.
Transformed Composite Section in Service properties are used with external loads applied to the composite precast beam.

PRESTRESSING STEEL TENDONS

ID	Qty	Grade MPa	Type *	Strand Size	Offsets x m	Offsets y mm	End Offset & Type Left ** m	End Offset & Type Right ** m	Tendon Area mm^2	Jacking Force Pj kN	Jacking Force %fpu
1	6.000	1860	LRS	09 (3/8")	0.000 3.120	30.0 30.0	0.000 B	0.000 B	328.80	366.94	0.60

note: * Type = LRS - Low-Relaxation Strand, SRS - Stress-Relieved Strand, PB - Plain Bar,
DB - Deformed Bar, SW - Single Wire
** End Types = B - Fully Bonded (B), D - Debonded (D), C - Cut (C), F - Full Develop (F) (fully developed)

Calculated Losses: Initial = 3.8%, Final = 13.7%
Maximum Total Prestress Forces: Pj(jacking) = 366.94 kN,
Pi(transfer) = 352.87 kN,
Pe(effective) = 316.56 kN @ x = 1.560 m,

See the "Development Length" text report for details of the strand transfer and development lengths

TRANSVERSE SHEAR STEEL

Shear Stirrups

From m	To m	Grade MPa	Size	# of Legs	Total Area mm^2	Spacing mm
0.000	3.120	400	15M	2	400.0	0.0

Interface Shear Ties

From m	To m	Grade MPa	Size	# of Legs	Total Area mm^2	Spacing mm
0.000	3.120	400	15M	0	0.0	0.0

APPLIED LOADS

Load Group & Type	Stages Applied & Distribution	Load Details (left to right)
HCS Self Weight D: DL, General	Transfer to Final Service No Load Distribution	HCS Self Weight- Area: 2.36 kN/m^2 full length, 1.2 m wide
Topping D: DL, General	CIP Placement to Final Service No Load Distribution	Topping- Area: 1.625 kN/m^2 full length, 1.2 m wide
DL D: DL, General	Completion to Final Service No Load Distribution	SDL- Area: 2.5 kN/m^2 full length, 1.2 m wide
LL L: LL, General	Final Service stage only No Load Distribution	LL- Area: 5 kN/m^2 full length, 1.2 m wide

Some load groups are generated automatically by Concise Beam.

LOAD COMBINATIONS

Serviceability (SLS) & Fatigue (FLS) Limit State Combinations (used individually)
SLS Stress : 1.00P + 1.00D + 1.00F + 1.00T + 1.00L + 1.00L1 + 1.00Lr + 1.00R + 1.00S + 1.00Ws + 0.60Wu
SLS Deflect : 1.00P + 1.00D + 1.00F + 1.00T + 1.00L + 1.00L1 + 1.00Lr + 1.00R + 1.00S
FLS Fatigue : 1.00P + 1.00D + 1.00F + 1.00L + 1.00L1 + 1.00Lr

Ultimate (Strength) Limit State (ULS) Combinations (searched collectively to obtain envelope)
1: Case 1 : 1.15D + 1.50L + 0.40Lr
2: Case 2 : 1.15D + 0.90L + 1.50Lr
3: Case 3 : 1.30D

COMBINED ANALYSIS IN SERVICE (external loads only)

Station	SLS (stress) Load Combination Moment	SLS (stress) Load Combination Moment	ULS Load Envelopes Shear			ULS Load Envelopes Moment		
x m	Sustained t.m	Total Load t.m min	Total Load t.m max	Total Load kN min	Total Load kN max	Govern. Combo. min	Govern. Combo. max	Total Load t.m min	Total Load t.m max	Govern. Combo. min	Govern. Combo. max
0.000	0.00	0.00	0.00	15.78	28.00	3	1	0.00	0.00	1	1
0.250	0.50	0.50	0.50	13.26	23.52	3	1	0.37	0.66	3	1

Project: BUID Dissertation - Composite action of Hollow Core slab
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0.562	1.01	1.01	1.01	10.10	17.92	3	1	0.74	1.31	3	1
0.874	1.38	1.38	1.38	6.94	12.32	3	1	1.01	1.80	3	1
1.186	1.61	1.61	1.61	3.79	6.72	3	1	1.18	2.10	3	1
1.498	1.71	1.71	1.71	0.63	1.12	3	1	1.25	2.22	3	1
1.560	1.71	1.71	1.71	0.00	0.00	1	1	1.26	2.23	3	1
1.622	1.71	1.71	1.71	-1.12	-0.63	1	3	1.25	2.22	3	1
1.810	1.67	1.67	1.67	-4.48	-2.53	1	3	1.22	2.17	3	1
1.934	1.61	1.61	1.61	-6.72	-3.79	1	3	1.18	2.10	3	1
2.246	1.38	1.38	1.38	-12.32	-6.94	1	3	1.01	1.80	3	1
2.558	1.01	1.01	1.01	-17.92	-10.10	1	3	0.74	1.31	3	1
2.870	0.50	0.50	0.50	-23.52	-13.26	1	3	0.37	0.66	3	1
3.120	0.00	0.00	0.00	-28.00	-15.78	1	3	0.00	0.00	1	1

COMBINED SUPPORT REACTIONS, ALL STAGES
(+ve = upwards, counter-clockwise)

Unfactored Load Group Effects

Load Group	Initial Lifting Left Vertical kN	Initial Lifting Right Vertical kN	Erection Lifting Left Vertical kN	Erection Lifting Right Vertical kN	During CIP Pour Left Vertical kN	During CIP Pour Right Vertical kN	In Service Left Vertical kN	In Service Left Torsion t.m	In Service Right Vertical kN	In Service Right Torsion t.m
HCS Self Wei	4.42	4.42	4.42	4.42	4.42	4.42	4.42	0.00	4.42	0.00
Topping					3.04	3.04	3.04	0.00	3.04	0.00
DL							4.68	0.00	4.68	0.00
LL							9.36	0.00	9.36	0.00

Load Envelope Effects

Load Envelope	Initial Lifting Left Vertical kN	Initial Lifting Right Vertical kN	Erection Lifting Left Vertical kN	Erection Lifting Right Vertical kN	During CIP Pour Left Vertical kN	During CIP Pour Right Vertical kN	In Service Left Vertical[*] kN	In Service Left Torsion[*] t.m	In Service Right Vertical[*] kN	In Service Right Torsion[*] t.m
SLS DL							12.14	0.00	12.14	0.00
SLS Sustain							21.50	0.00	21.50	0.00
SLS Minimum	4.42	4.42	4.42	4.42	7.46	7.46	21.50	0.00	21.50	0.00
SLS Maximum	4.42	4.42	4.42	4.42	7.46	7.46	21.50	0.00	21.50	0.00
ULS Minimum							15.78 [3]	0.00 [1]	15.78 [3]	0.00 [1]
ULS Maximum							28.00 [1]	0.00 [1]	28.00 [1]	0.00 [1]

|* Governing ULS Load Combination (below)

CONCRETE STRESS RESULTS (UNCRACKED ANALYSIS)
(+ve = compression, -ve = tension)

Location	x m	Stress MPa	Limit * MPa	Overstress Notice	
STRESSES AT TRANSFER					
Critical Compression					
Top of Beam	1.560	0.34	16.80	0%	
Bottom of Beam	0.936	6.55	16.80	0%	
					Longitudinal Tensile Rebar Needed (mm^2)
Critical Tension					Required Provided Additional
Top of Beam	2.683	-0.17	-2.64	0%	
Bottom of Beam	0.000	0.00	-2.64	0%	
STRESSES DURING INITIAL LIFTING					
Critical Compression					
Top of Beam	1.560	0.34	18.00	0%	
Bottom of Beam	0.936	6.55	18.00	0%	
					Longitudinal Tensile Rebar Needed (mm^2)
Critical Tension					Required Provided Additional
Top of Beam	2.683	-0.17	-2.73	0%	
Bottom of Beam	0.000	0.00	-2.73	0%	
STRESSES DURING ERECTION LIFTING					
Critical Compression					
Top of Beam	1.560	0.37	24.00	0%	
Bottom of Beam	0.936	6.16	24.00	0%	
					Longitudinal Tensile Rebar Needed (mm^2)
Critical Tension					Required Provided Additional
Top of Beam	2.683	-0.13	-3.15	0%	
Bottom of Beam	0.000	0.00	-3.15	0%	
STRESSES DURING CAST-IN-PLACE POUR					
Critical Compression					
Top of Beam	1.560	1.05	24.00	0%	
Bottom of Beam	2.683	6.12	24.00	0%	
Critical Tension					
Top of Beam	0.000	0.00	-3.94	0%	
Bottom of Beam	0.000	0.00	-3.94	0%	
STRESSES IN SERVICE					
Critical Compression					
Top of Beam	1.560	1.58	24.00	0%	
Bottom of Beam	2.683	4.98	24.00	0%	
Top of CIP Pour	1.560	1.15	16.80	0%	
Critical Tension					
Top of Beam	0.000	0.00	-6.30	0%	Class U member - not cracked
Bottom of Beam	0.000	0.00	-6.30	0%	Class U member - not cracked
Top of CIP Pour	0.000	0.00	-3.30	0%	
STRESSES IN SERVICE (SUSTAINED LOADS ONLY)					
Critical Compression					
Top of Beam	1.560	1.58	18.00	0%	
Bottom of Beam	2.683	4.98	18.00	0%	

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Problem: HCS 150 Composite

* Tensile stress limit given is for Class T (controlled cracking). Beyond this limit crack control is required.
  Tensile stress limit given for the cast-in-place pour is the flexural cracking strength of the concrete.

	At Transfer	During Lifting	In Service
Modulus of Rupture, fr =	-3.30 MPa	-3.41 MPa	-3.94 MPa
Strength Required for Transfer, f'ci =	10.9 MPa	(f'c specified =	28.0 MPa)
Strength Required for Initial Lifting, f'c =	10.9 MPa	(f'c assumed =	30.0 MPa)

CRACK CONTROL
(+ve = compression, -ve = tension)

CRACK CONTROL STEEL AND SPACING

	Bottom of Beam	Top of Beam		
cc	0.0	0.0	mm	Clear concrete cover to steel closest to tension face
fs	0	0	MPa	Steel stress nearest to tension face (after decompression) for crack control
Max spacing	0.0	0.0	mm	Maximum centre-to-centre spacing of steel closest to tension face to control cracking

Beam not cracked, cracking is controlled, or crack depth is less than concrete cover.

DEFLECTION ESTIMATE AT ALL STAGES

Design Code Used: ACI 318-11 (customized)

A. Deflections at All Stages
(-ve = deflection down, +ve = camber up)

	Net Deflection					Change in Deflection			
Location x m Column	Net @ Transfer mm A	Net @ Erection mm B	Net @ Completion mm C	Net DL @ Final mm D	Net Total @ Final mm E	DL growth + LL mm E - C	LL alone mm E - D	Span/Deflection DL growth + LL L / (E-C)	Span/Deflection LL alone L / (E-D)
0.000	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0	0
0.250	0.5	1.1	1.1	0.7	0.7	-0.4	0.0	8037	0
0.562	1.1	2.2	2.3	1.5	1.5	-0.8	0.0	3733	0
0.874	1.5	3.1	3.1	1.9	1.9	-1.2	0.0	2596	0
1.186	1.8	3.6	3.7	2.2	2.2	-1.4	0.0	2153	0
1.498	1.9	3.8	3.9	2.3	2.3	-1.6	0.0	2006	0
1.560	1.9	3.8	3.9	2.3	2.3	-1.6	0.0	2002	0
1.622	1.9	3.8	3.9	2.3	2.3	-1.6	0.0	2006	0
1.810	1.8	3.7	3.8	2.3	2.3	-1.5	0.0	2067	0
1.934	1.8	3.6	3.7	2.2	2.2	-1.4	0.0	2153	0
2.246	1.5	3.1	3.1	1.9	1.9	-1.2	0.0	2596	0
2.558	1.1	2.2	2.3	1.5	1.5	-0.8	0.0	3733	0
2.870	0.5	1.1	1.1	0.7	0.7	-0.4	0.0	8037	0
3.120	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0	0

Col. A: Net deflection at transfer includes prestressing and beam weight on temporary supports.
Col. B: Net deflection at erection includes prestressing and all dead loads applied before the cast-in-place pour plus long-time deflection growth of the prestressing and beam weight up to erection
Col. C: Net deflection at completion of construction includes prestressing and all dead loads plus long-time deflection growth of the prestressing and dead load up to completion
Col. D: Net DL deflection at final includes prestressing, all dead loads, and sustained live loads, plus long-time deflection growth.
Col. E: Net total deflection at final includes prestressing, all dead loads, and all live loads, plus long-time deflection growth.

Deflection/camber is measured from the cast shape of the beam before release of prestressing.

Deflection growth is estimated by use of the PCI suggested multipliers - see the Deflection Multipliers report.

Span/Deflection Limits: DL growth + LL = L / 480 for non-structural attachments
L / 240 otherwise
LL alone = L / 360 for floors
L / 180 for roofs

SUPPORT ROTATION AND CHANGE OF LENGTH ESTIMATE AT ALL STAGES

Design Code Used: ACI 318-11 (customized)

B. Unrestrained Support Rotations at All Stages
(+ve = clockwise rotation)

	Net Rotation					Change in Rotation	
Support Location Column	Net @ Transfer degrees A	Net @ Erection degrees B	Net @ Completion degrees C	Net DL @ Final degrees D	Net Total @ Final degrees E	DL growth + LL degrees E - C	LL alone degrees E - D
Left	-0.1251	-0.2517	-0.2593	-0.1692	-0.1692	0.0901	0.0000
Right	0.1251	0.2517	0.2593	0.1692	0.1692	-0.0901	0.0000

C. Unrestrained Longitudinal Change of Length Due to Creep and Shrinkage
(-ve = shortening, +ve = elongation)

Elastic Shortening = -0.35 mm

	Total Change of Length (after elastic shortening)				Difference in Change		
	Erection mm B	Completion mm C	Final mm D		to Compl. mm C - B	to Final mm D - C	to Final mm D - B
Creep	-0.32	-0.44	-0.67		-0.12	-0.23	-0.35
Shrink.	-0.93	-1.37	-1.73		-0.44	-0.37	-0.80

Project: BUID Dissertation - Composite action of Hollow Core slab
Problem: HCS 150 Composite

| Total | | -1.25 | -1.81 | -2.41 | | -0.55 | -0.60 | -1.15 |

FLEXURAL DESIGN CHECK

Design Code Used: ACI 318-11 (customized)
Concrete compressive stress-strain model used: PCA Parabola-Rectangle Curve

Modulus of Rupture of Precast Concrete, fr = 3.94 MPa (tension)

x m	Design Moment Mu t.m	Cracking Moment Mcr t.m	Minimum Required Strength t.m	Design Strength ØMn t.m	Depth in Compression c mm	Net Tensile Strain	Flexural Classication	Ø	Warnings & Notes
0.000	0.00	2.77	0.00	0.00	0.4	1.3029	Tension	0.75	
0.250	0.66	5.40	1.31	2.58	8.2	0.0645	Tension	0.75	
0.562	1.31	7.21	2.63	4.78	15.0	0.0341	Tension	0.76	
0.874	1.80	7.13	3.59	6.07	18.3	0.0273	Tension	0.80	
1.186	2.10	7.08	4.20	7.43	21.4	0.0229	Tension	0.84	
1.498	2.22	7.06	4.45	8.87	24.9	0.0193	Tension	0.88	
1.560	2.23	7.05	4.45	9.54	26.5	0.0180	Tension	0.89	
1.622	2.22	7.06	4.45	8.87	24.9	0.0193	Tension	0.88	
1.810	2.17	7.06	4.34	8.00	22.8	0.0214	Tension	0.86	
1.934	2.10	7.08	4.20	7.43	21.4	0.0229	Tension	0.84	
2.246	1.80	7.13	3.59	6.07	18.3	0.0273	Tension	0.80	
2.558	1.31	7.21	2.63	4.78	15.0	0.0341	Tension	0.76	
2.870	0.66	5.40	1.31	2.58	8.2	0.0645	Tension	0.75	
3.120	0.00	2.77	0.00	0.00	0.4	1.3029	Tension	0.75	
Points of Maximum and Minimum Factored Moment									
1.560	2.23	7.05	4.45	9.54	26.5	0.0180	Tension	0.89	
0.000	0.00	1.40	0.00	0.00	0.4	0.2370	Tension	0.75	
Points of Maximum Ratio of Factored Moment to Design Strength									
2.246	1.80	7.13	3.59	6.07	18.3	0.0273	Tension	0.80	
0.000	0.00	1.40	0.00	0.00	0.4	0.2370	Tension	0.75	
Points of Maximum Ratio of Minimum Strength to Design Strength									
2.246	1.80	7.13	3.59	6.07	18.3	0.0273	Tension	0.80	
0.000	0.00	1.40	0.00	0.00	0.4	0.2370	Tension	0.75	

SHEAR DESIGN CHECK

Design Code Used: ACI 318-11 (customized)

x m	Design Shear Vu kN	Prestress Component Vp kN	Concrete Strength ØVc kN	Core Fill Strength ØVc (core) kN	Required Stirrups ØVs kN	Strength Provided Stirrups ØVs kN	Strength Provided Total ØVn kN	Warnings & Notes
0.000	25.53	0.00	29.88	0.00	0.00	0.00	29.88	3
0.250	23.52	0.00	59.97	0.00	0.00	0.00	59.97	
0.562	17.92	0.00	66.50	0.00	0.00	0.00	66.50	
0.874	12.32	0.00	42.13	0.00	0.00	0.00	42.13	
1.186	6.72	0.00	25.16	0.00	0.00	0.00	25.16	
1.498	1.12	0.00	25.16	0.00	0.00	0.00	25.16	
1.560	0.00	0.00	25.16	0.00	0.00	0.00	25.16	
1.560	0.00	0.00	-25.16	0.00	0.00	0.00	-25.16	
1.622	-1.12	0.00	-25.16	0.00	0.00	0.00	-25.16	
1.810	-4.48	0.00	-25.16	0.00	0.00	0.00	-25.16	
1.934	-6.72	0.00	-25.16	0.00	0.00	0.00	-25.16	
2.246	-12.32	0.00	-42.13	0.00	0.00	0.00	-42.13	
2.558	-17.92	0.00	-66.50	0.00	0.00	0.00	-66.50	
2.870	-23.52	0.00	-59.97	0.00	0.00	0.00	-59.97	
3.120	-25.53	0.00	-29.88	0.00	0.00	0.00	-29.88	3

Warnings & Notes
3 - Note, design shear force at critical section near support used [ACI 318-11::11.1.3].

SHEAR TRANSVERSE REINFORCING DESIGN CHECK

Design Code Used: ACI 318-11 (customized)

x m	Shear Steel Grade fy MPa	Shear Steel Required Av/s mm^2/m	Shear Steel Provided Av/s mm^2/m	Stirrup Provided Av mm^2	Stirrup Spacing Provided s mm	Stirrup Spacing Max. Allow s mm	Warnings & Notes
0.000	400	0	0	400.00	0.0	161.3	4
0.250	400	0	0	400.00	0.0	161.3	
0.562	400	0	0	400.00	0.0	161.3	
0.874	400	0	0	400.00	0.0	161.3	
1.186	400	0	0	400.00	0.0	161.3	
1.498	400	0	0	400.00	0.0	161.3	
1.560	400	0	0	400.00	0.0	161.3	
1.560	400	0	0	400.00	0.0	161.3	
1.622	400	0	0	400.00	0.0	161.3	
1.810	400	0	0	400.00	0.0	161.3	
1.934	400	0	0	400.00	0.0	161.3	
2.246	400	0	0	400.00	0.0	161.3	
2.558	400	0	0	400.00	0.0	161.3	
2.870	400	0	0	400.00	0.0	161.3	
3.120	400	0	0	400.00	0.0	161.3	4

Warnings & Notes
4 - Note, design shear force at critical section near support used [ACI 318-11::11.1.3].
Note, shear steel requirements for pre-tension bursting have NOT been included (calculation option S8).
Note, additional long. steel in compression side of section has been reduced [ACI 318-11::11.5.3.9].
* Portion of the total stirrup area required to resist torsional shear flow (one leg around periphery).
** The allowable reduction in Al within the flexural compression zone.

HORIZONTAL SHEAR DESIGN CHECK BY SECTION

Design Code Used: ACI 318-11 (customized)

Project: BUID Dissertation - Composite action of Hollow Core slab
Problem: HCS 150 Composite

Top of precast beam is considered intentionally roughened.

x m	Horizontal Shear Vu kN	Strength with no ties kN	Maximum Limit ØVnh Max kN	Required Ties Av/s mm^2/m	Tie Size Provided Av mm^2	Spacing Required s mm	Spacing Provided s mm	Strength Required ØVnh kN	Strength Provided ØVnh kN	Warnings & Notes
0.000	25.53	87.26	545.38	0	0.0	0.0	0.0	25.53	87.26	1
0.250	23.52	87.26	545.38	0	0.0	0.0	0.0	23.52	87.26	1
0.562	17.92	87.26	545.38	0	0.0	0.0	0.0	17.92	87.26	1
0.874	12.32	87.26	545.38	0	0.0	0.0	0.0	12.32	87.26	1
1.186	6.72	87.26	545.38	0	0.0	0.0	0.0	6.72	87.26	1
1.498	1.12	87.26	545.38	0	0.0	0.0	0.0	1.12	87.26	1
1.560	0.00	87.26	545.38	0	0.0	0.0	0.0	0.00	87.26	1
1.622	-1.12	-87.26	-545.38	0	0.0	0.0	0.0	-1.12	-87.26	1
1.810	-4.48	-87.26	-545.38	0	0.0	0.0	0.0	-4.48	-87.26	1
1.934	-6.72	-87.26	-545.38	0	0.0	0.0	0.0	-6.72	-87.26	1
2.246	-12.32	-87.26	-545.38	0	0.0	0.0	0.0	-12.32	-87.26	1
2.558	-17.92	-87.26	-545.38	0	0.0	0.0	0.0	-17.92	-87.26	1
2.870	-23.52	-87.26	-545.38	0	0.0	0.0	0.0	-23.52	-87.26	1
3.120	-25.53	-87.26	-545.38	0	0.0	0.0	0.0	-25.53	-87.26	1

Warnings & Notes
1 - Note, no ties required [ACI 318-11::17.5.3.3].

HORIZONTAL SHEAR DESIGN CHECK BY MOMENT REGION

Design Code Used: ACI 318-11 (customized)

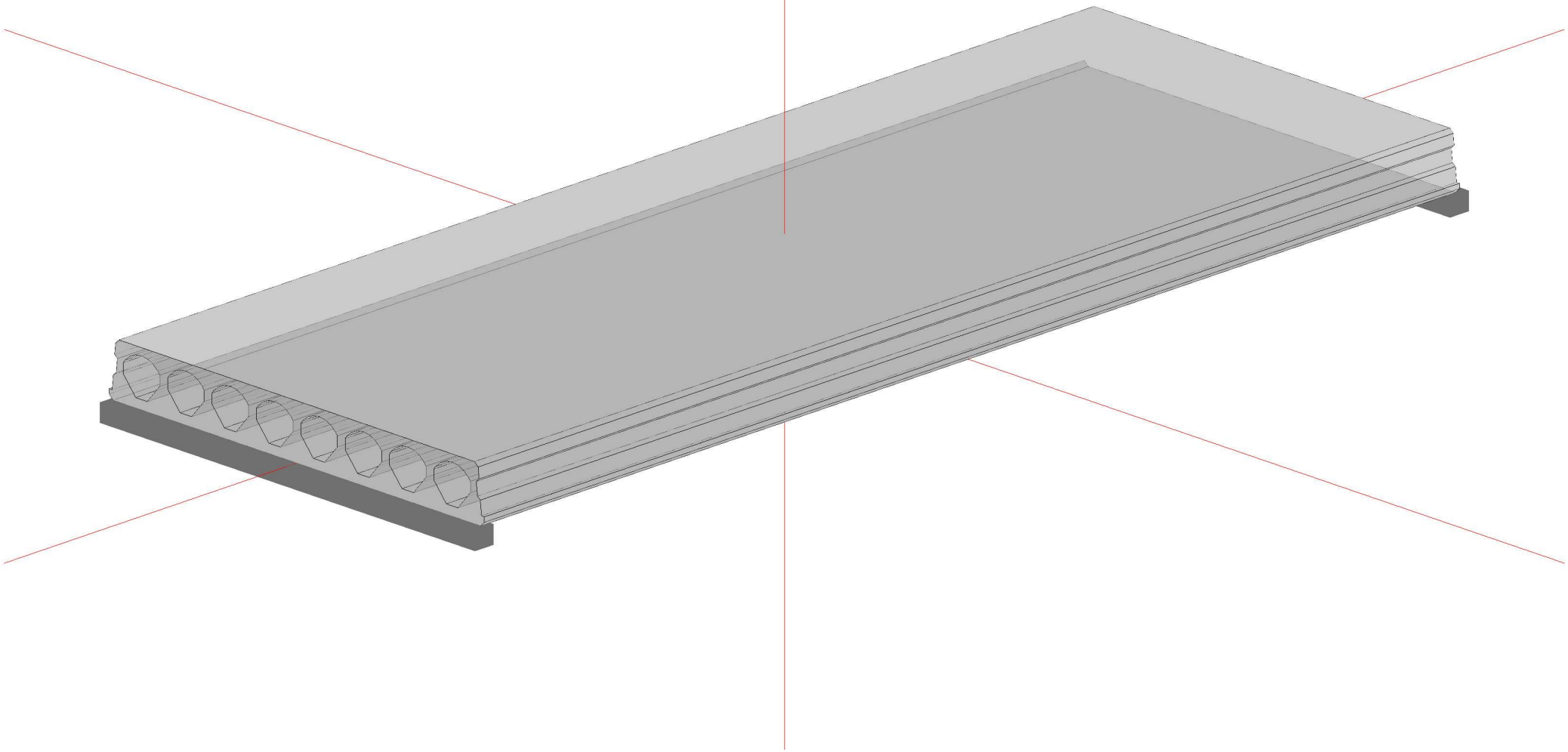
Top of precast beam is considered intentionally roughened.

Region of Beam x m	Shear Length lv m	Peak Moment M t.m	Horizontal Shear Fh kN	Strength with no ties kN	Maximum Limit ØVnh Max kN	Tie Area * Required Acs mm^2	Tie Area Provided Acs mm^2	Maximum Spacing s mm	Warnings & Notes
0.000 to 1.560	1.560	2.23	141.39	735.83	7403.20	0.0	0.0	260.0	
1.560 to 3.120	1.560	2.23	141.39	735.83	7403.20	0.0	0.0	260.0	

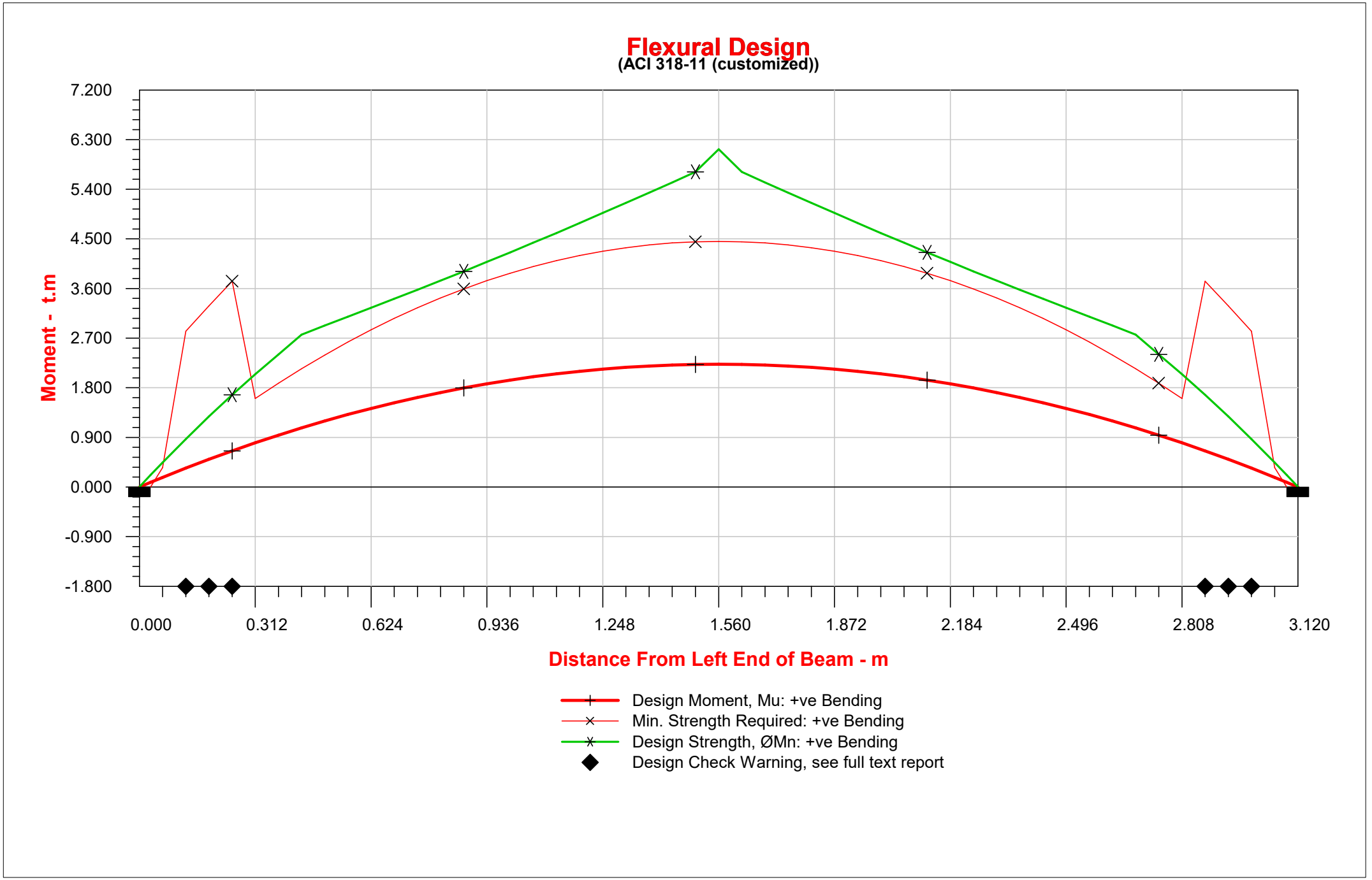
* Required ties should be distributed in proportion to distribution of shear force (or stirrups).

Project: BUID Dissertation - Composite action of Hollow Core slab
Problem: HCS 150 non composite

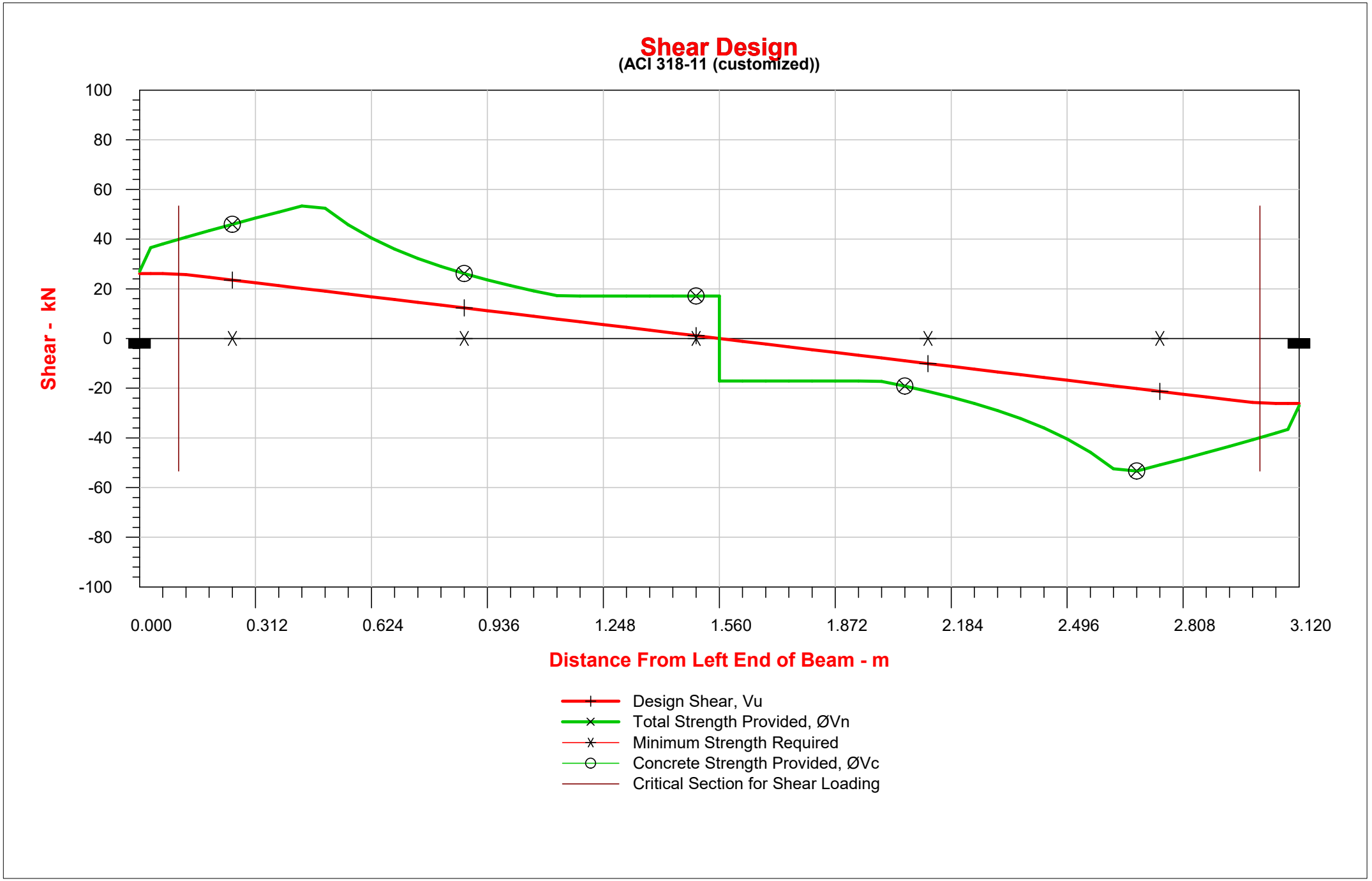
Hollow core slab 150mm considered as non-composite with 65mm structural screed.
(Structural screed is considered as additional load)



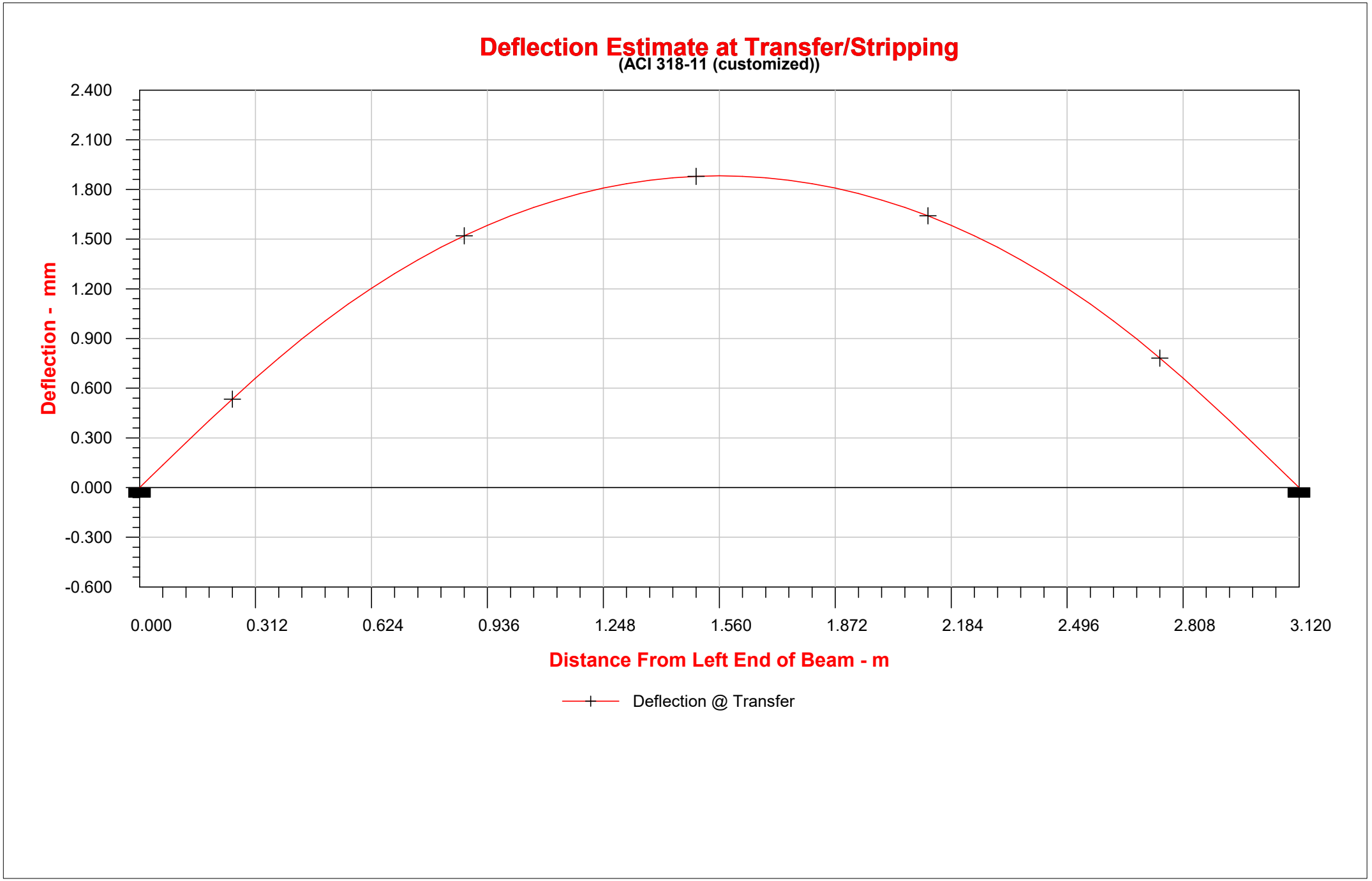
Project: BUID Dissertation - Composite action of Hollow Core slab
Problem: HCS 150 non composite



Project: BUID Dissertation - Composite action of Hollow Core slab
Problem: HCS 150 non composite



Project: BUID Dissertation - Composite action of Hollow Core slab
Problem: HCS 150 non composite



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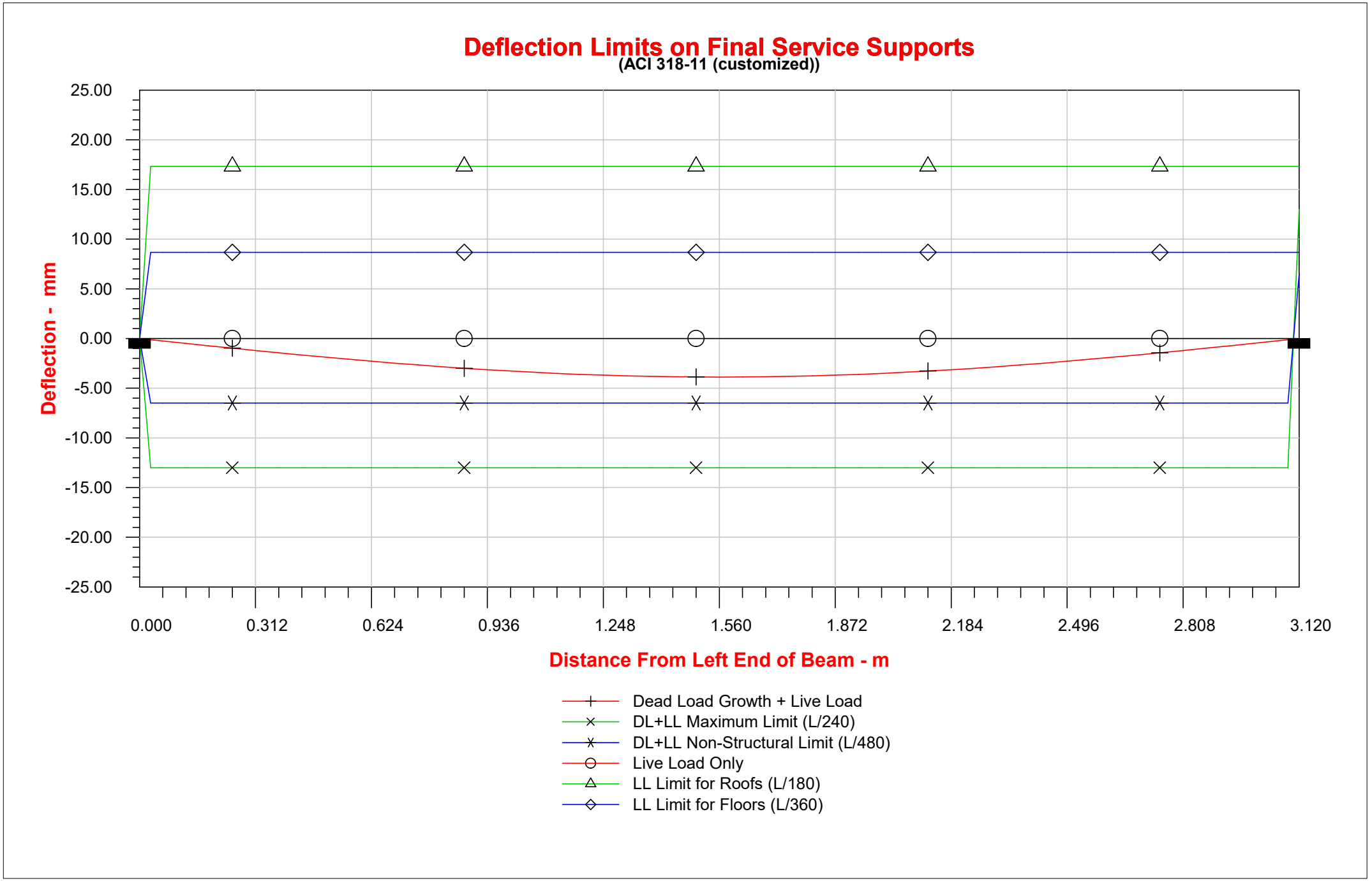

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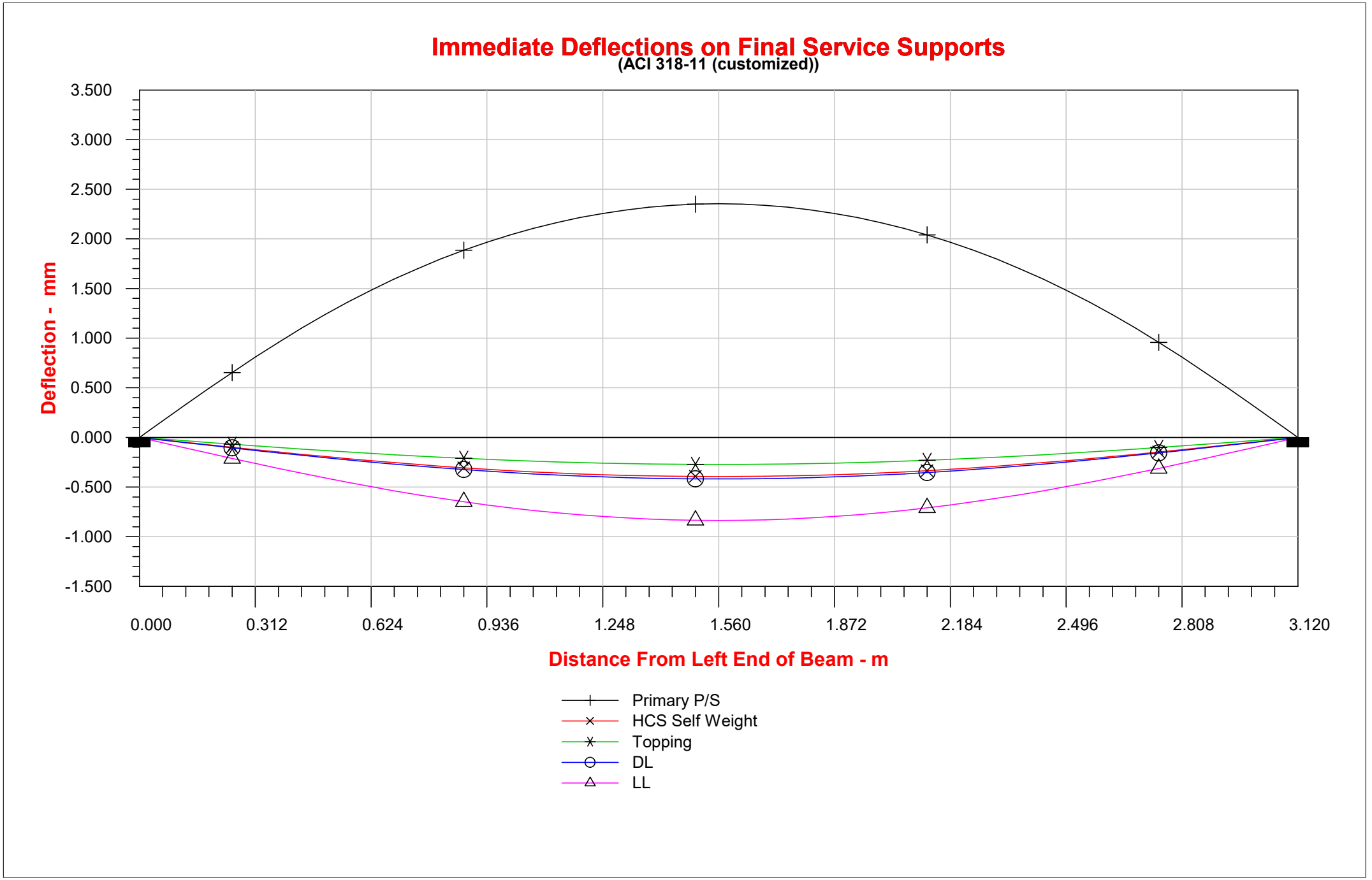
Problem: HCS 150 non composite



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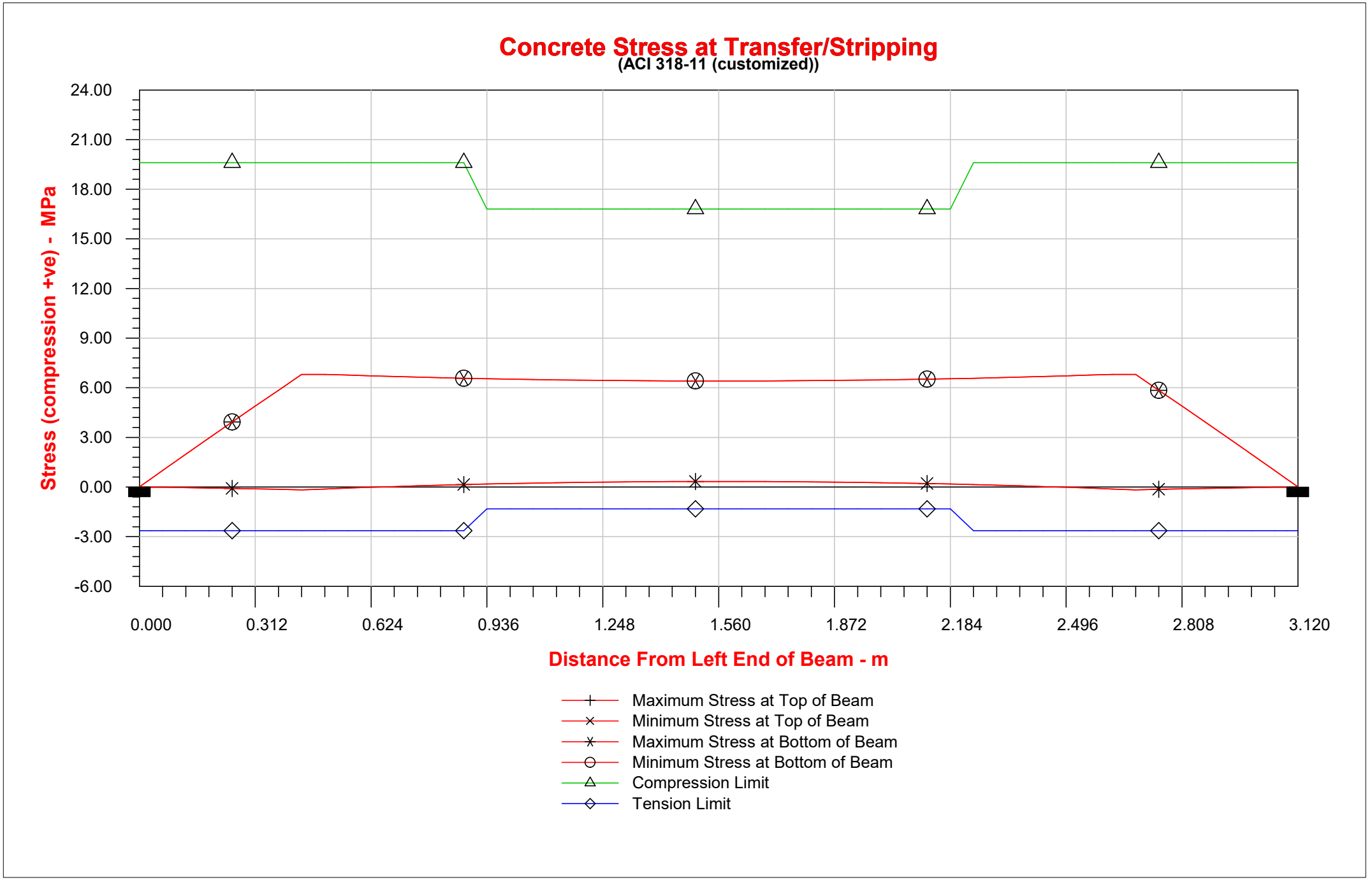
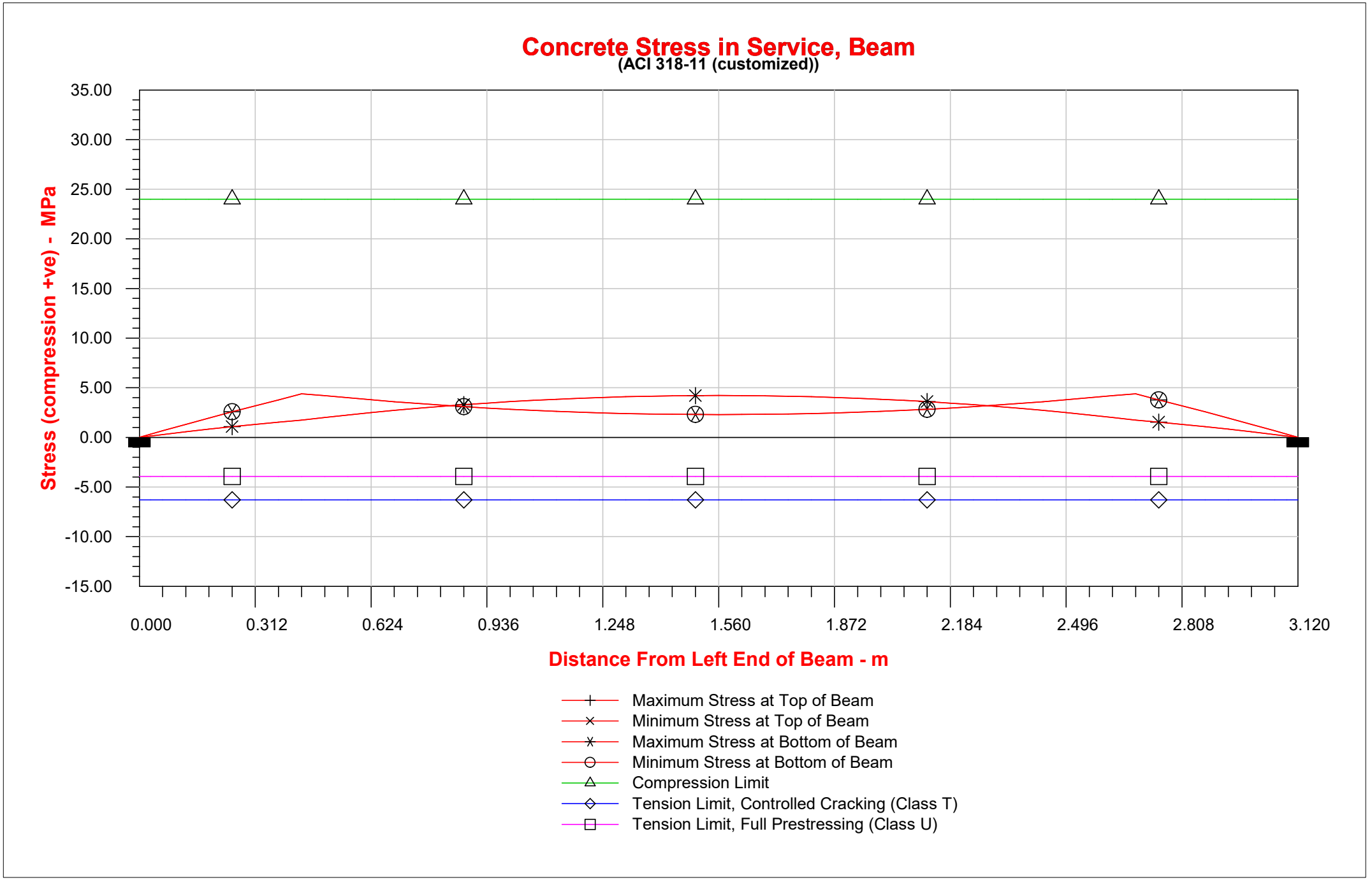
Problem: HCS 150 non composite



Project: BUID Dissertation - Composite action of Hollow Core slab
Problem: HCS 150 non composite



Project: BUID Dissertation - Composite action of Hollow Core slab
Problem: HCS 150 non composite

SUMMARY REPORT

Design Code Used: ACI 318-11 (customized)

NON-DEFAULT OPTION SETTINGS

** OFF ** G2: Use PCI Standard Design Practice, TR-7-05 (ACI codes only)
** ON ** P1: Vary user defined losses along beam
** OFF ** F7: Reduce ϕ in the development length of strands (CSA A23.3 only)
** OFF ** F8: Use a rectangular stress block at concrete ultimate strain
** ON ** S10: Use the ultimate section capacity for horizontal shear (moment region check)
** OFF ** D3: Have Concise Beam calculate the long-term deflection multipliers for prestressed Beams

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CONCRETE MATERIAL PROPERTIES

		Precast Beam	
Concrete Density	Wt =	2400	kg/m^3
Compressive Strength	f'c =	40.0	MPa
Modulus of Elasticity	Ec =	31783	MPa
Strength at Transfer	f'c =	28.0	MPa
Modulus of Elast. at Transfer	Ec =	26591	MPa
Strength at Lifting	f'c =	30.0	MPa
Modulus of Elast. at Lifting	Ec =	26621	MPa

Cement Content = 410 kg/m^3
Air Content = 5.00 %
Slump = 50.0 mm
Aggregate Mix = 0.40 (fine to total aggregate ratio)
Aggregate Size = 20.0 mm
Basic Shrinkage Strain = 780.000E-6

Construction Schedule
Age at Transfer = 0.75 days
Age at Erection = 40 days
Age at Cast-in-Place Pour = 50 days
Age Cast-in-Place is Composite = 53 days
Age Construction is Complete = 143 days

Curing Method = Moist
Relative Humidity in Service = 70 %
Ambient Temperature in Service = 20 deg C

PRECAST BEAM LAYOUT

Segment/Length			Section Identification			Offset	
No	From m	To m	Length m	Folder Name	Section Name	Section Type	Z mm	Y mm
1	0.000	3.120	3.120	Standard HC	HCS150	Hollowcore	0.0	0.0

* Long offset from left end of beam. Transverse offset from top of precast to top of opening
for horizontal orientation or from center of precast to center of opening for vertical orientation.

Span Length at Transfer = 3.120 m, Centre of Supports, Left @ 0.000 m, Right @ 3.120 m
Span Length during Lift = 3.120 m, Centre of Supports, Left @ 0.000 m, Right @ 3.120 m Loop Height = 0.0 mm
Span Length in Service = 3.120 m, Centre of Supports, Left @ 0.000 m, Right @ 3.120 m
Total Beam Length = 3.120 m, Bearing Length, Left = 60.0 mm, Right = 60.0 mm

First flexural frequency of beam is approximately 17.98 Hz

GROSS PRECAST SECTION PROPERTIES (NON-COMPOSITE)
(based on Ec of the precast beam - transformed area of rebar and strand NOT included)

Seg. No.	Section Properties A mm^2	I mm^4	yb mm	Section Height mm	Section Width mm	Shear Width mm	Volume / Surface mm	Section Moduli Sb mm^3	St mm^3
1	100667	275.353E+6	71.0	150.0	1200.0	213.0	38.00	-3.878E+6	3.485E+6

UNCRACKED SECTION PROPERTIES SUMMARY

	Net Precast Section at Transfer (based on Eci) (include rebar,deduct strand)			Transformed Precast Section at Transfer (based on Eci) (include rebar and strand)			Transformed Precast Section in Service (based on Ec) (include rebar and strand)		
x m	A mm^2	I mm^4	yb mm	A mm^2	I mm^4	yb mm	A mm^2	I mm^4	yb mm
0.000	100338	274.798E+6	71.1	100669	275.356E+6	71.0	100669	275.356E+6	71.0
0.250	100338	274.798E+6	71.1	101970	277.515E+6	70.5	101724	277.112E+6	70.6
0.562	100338	274.798E+6	71.1	102811	278.882E+6	70.1	102407	278.228E+6	70.3
0.874	100338	274.798E+6	71.1	102811	278.882E+6	70.1	102407	278.228E+6	70.3
1.186	100338	274.798E+6	71.1	102811	278.882E+6	70.1	102407	278.228E+6	70.3
1.498	100338	274.798E+6	71.1	102811	278.882E+6	70.1	102407	278.228E+6	70.3
1.560	100338	274.798E+6	71.1	102811	278.882E+6	70.1	102407	278.228E+6	70.3
1.622	100338	274.798E+6	71.1	102811	278.882E+6	70.1	102407	278.228E+6	70.3
1.810	100338	274.798E+6	71.1	102811	278.882E+6	70.1	102407	278.228E+6	70.3
1.934	100338	274.798E+6	71.1	102811	278.882E+6	70.1	102407	278.228E+6	70.3
2.246	100338	274.798E+6	71.1	102811	278.882E+6	70.1	102407	278.228E+6	70.3
2.558	100338	274.798E+6	71.1	102811	278.882E+6	70.1	102407	278.228E+6	70.3
2.870	100338	274.798E+6	71.1	101970	277.515E+6	70.5	101724	277.112E+6	70.6
3.120	100338	274.798E+6	71.1	100669	275.356E+6	71.0	100669	275.356E+6	71.0

These section properties can used to calculate uncracked concrete stresses using the following guidelines.

Net Precast Section at Transfer properties are used with the initial prestress after transfer (after elastic shortening loss).
Transformed Precast Section at Transfer properties are used with the precast beam self-weight.
Transformed Precast Section in Service properties are used with external loads applied to the non-composite precast beam.

PRESTRESSING STEEL TENDONS

ID	Qty	Grade MPa	Type *	Strand Size	Offsets x m	Offsets y mm	End Offset & Type Left ** m	End Offset & Type Right ** m	Tendon Area mm^2	Jacking Force Pj kN	Jacking Force %fpu

Project: BUID Dissertation - Composite action of Hollow Core slab
Problem: HCS 150 non composite

1	6.000	1860	LRS	09 (3/8")	0.000 3.120	30.0 30.0	0.000 B	0.000 B	328.80	366.94	0.60	

note: * Type = LRS - Low-Relaxation Strand, SRS - Stress-Relieved Strand, PB - Plain Bar,
DB - Deformed Bar, SW - Single Wire
** End Types = B - Fully Bonded (B), D - Debonded (D), C - Cut (C), F - Full Develop (F) (fully developed)

Calculated Losses: Initial = 3.8%, Final = 13.6%
Maximum Total Prestress Forces: Pj(jacking) = 366.94 kN,
Pi(transfer) = 352.87 kN,
Pe(effective) = 317.16 kN @ x = 1.560 m,

See the "Development Length" text report for details of the strand transfer and development lengths

TRANSVERSE SHEAR STEEL

Shear Stirrups

From m	To m	Grade MPa	Size	# of Legs	Total Area mm^2	Spacing mm
0.000	3.120	400	15M	2	400.0	0.0

Interface Shear Ties

From m	To m	Grade MPa	Size	# of Legs	Total Area mm^2	Spacing mm
0.000	3.120	400	15M	0	0.0	0.0

APPLIED LOADS

Load Group & Type	Stages Applied & Distribution	Load Details (left to right)
HCS Self Weight D: DL, General	Transfer to Final Service No Load Distribution	HCS Self Weight- Area: 2.36 kN/m^2 full length, 1.2 m wide
Topping D: DL, General	Grouting to Final Service No Load Distribution	Topping- Area: 1.625 kN/m^2 full length, 1.2 m wide
DL D: DL, General	Completion to Final Service No Load Distribution	SDL- Area: 2.5 kN/m^2 full length, 1.2 m wide
LL L: LL, General	Final Service stage only No Load Distribution	LL- Area: 5 kN/m^2 full length, 1.2 m wide

Some load groups are generated automatically by Concise Beam.

LOAD COMBINATIONS

Serviceability (SLS) & Fatigue (FLS) Limit State Combinations (used individually)
SLS Stress : 1.00P + 1.00D + 1.00F + 1.00T + 1.00L + 1.00L1 + 1.00Lr + 1.00R + 1.00S + 1.00Ws + 0.60Wu
SLS Deflect : 1.00P + 1.00D + 1.00F + 1.00T + 1.00L + 1.00L1 + 1.00Lr + 1.00R + 1.00S
FLS Fatigue : 1.00P + 1.00D + 1.00F + 1.00L + 1.00L1 + 1.00Lr

Ultimate (Strength) Limit State (ULS) Combinations (searched collectively to obtain envelope)
1: Case 1 : 1.15D + 1.50L + 0.40Lr
2: Case 2 : 1.15D + 0.90L + 1.50Lr
3: Case 3 : 1.30D

COMBINED ANALYSIS IN SERVICE (external loads only)

Station	SLS (stress) Load Combination		ULS Load Envelopes							
	Moment	Moment	Shear				Moment			
x	Sustained	Total Load	Total Load		Govern. Combo.		Total Load		Govern. Combo.	
m	t.m	t.m min	t.m max	kN min	kN max	min	max	t.m min	t.m max	min	max
0.000	0.00	0.00	0.00	15.78	28.00	3	1	0.00	0.00	1	1
0.250	0.50	0.50	0.50	13.26	23.52	3	1	0.37	0.66	3	1
0.562	1.01	1.01	1.01	10.10	17.92	3	1	0.74	1.31	3	1
0.874	1.38	1.38	1.38	6.94	12.32	3	1	1.01	1.80	3	1
1.186	1.61	1.61	1.61	3.79	6.72	3	1	1.18	2.10	3	1
1.498	1.71	1.71	1.71	0.63	1.12	3	1	1.25	2.22	3	1
1.560	1.71	1.71	1.71	0.00	0.00	1	1	1.26	2.23	3	1
1.622	1.71	1.71	1.71	-1.12	-0.63	1	3	1.25	2.22	3	1
1.810	1.67	1.67	1.67	-4.48	-2.53	1	3	1.22	2.17	3	1
1.934	1.61	1.61	1.61	-6.72	-3.79	1	3	1.18	2.10	3	1
2.246	1.38	1.38	1.38	-12.32	-6.94	1	3	1.01	1.80	3	1
2.558	1.01	1.01	1.01	-17.92	-10.10	1	3	0.74	1.31	3	1
2.870	0.50	0.50	0.50	-23.52	-13.26	1	3	0.37	0.66	3	1
3.120	0.00	0.00	0.00	-28.00	-15.78	1	3	0.00	0.00	1	1

COMBINED SUPPORT REACTIONS, ALL STAGES
(+ve = upwards, counter-clockwise)

Unfactored Load Group Effects

Load Group	Initial Lifting Left Vertical kN	Initial Lifting Right Vertical kN	Erection Lifting Left Vertical kN	Erection Lifting Right Vertical kN	During CIP Pour Left Vertical kN	During CIP Pour Right Vertical kN	In Service Left Vertical kN	In Service Left Torsion t.m	In Service Right Vertical kN	In Service Right Torsion t.m

Project: BUID Dissertation - Composite action of Hollow Core slab
Problem: HCS 150 non composite

HCS Self Wei	4.42	4.42	4.42	4.42	4.42	4.42	4.42	0.00	4.42	0.00
Topping					3.04	3.04	3.04	0.00	3.04	0.00
DL							4.68	0.00	4.68	0.00
LL							9.36	0.00	9.36	0.00

Load Envelope Effects

Load Envelope	Initial Lifting Left Vertical kN	Initial Lifting Right Vertical kN	Erection Lifting Left Vertical kN	Erection Lifting Right Vertical kN	During CIP Pour Left Vertical kN	During CIP Pour Right Vertical kN	In Service Left Vertical[*] kN	In Service Left Torsion[*] t.m	In Service Right Vertical[*] kN	In Service Right Torsion[*] t.m
SLS DL							12.14	0.00	12.14	0.00
SLS Sustain							21.50	0.00	21.50	0.00
SLS Minimum	4.42	4.42	4.42	4.42	7.46	7.46	21.50	0.00	21.50	0.00
SLS Maximum	4.42	4.42	4.42	4.42	7.46	7.46	21.50	0.00	21.50	0.00
ULS Minimum							15.78 [3]	0.00 [1]	15.78 [3]	0.00 [1]
ULS Maximum							28.00 [1]	0.00 [1]	28.00 [1]	0.00 [1]

|* Governing ULS Load Combination (below)

CONCRETE STRESS RESULTS (UNCRACKED ANALYSIS)
(+ve = compression, -ve = tension)

Location	x m	Stress MPa	Limit * MPa	Overstress Notice	
STRESSES AT TRANSFER					
Critical Compression					
Top of Beam	1.560	0.34	16.80	0%	
Bottom of Beam	0.936	6.55	16.80	0%	
					Longitudinal Tensile Rebar Needed (mm^2)
Critical Tension					Required / Provided / Additional
Top of Beam	0.437	-0.17	-2.64	0%	
Bottom of Beam	0.000	0.00	-2.64	0%	
STRESSES DURING INITIAL LIFTING					
Critical Compression					
Top of Beam	1.560	0.34	18.00	0%	
Bottom of Beam	0.936	6.55	18.00	0%	
					Longitudinal Tensile Rebar Needed (mm^2)
Critical Tension					Required / Provided / Additional
Top of Beam	0.437	-0.17	-2.73	0%	
Bottom of Beam	0.000	0.00	-2.73	0%	
STRESSES DURING ERECTION LIFTING					
Critical Compression					
Top of Beam	1.560	0.37	24.00	0%	
Bottom of Beam	0.936	6.17	24.00	0%	
					Longitudinal Tensile Rebar Needed (mm^2)
Critical Tension					Required / Provided / Additional
Top of Beam	2.683	-0.13	-3.15	0%	
Bottom of Beam	0.000	0.00	-3.15	0%	
STRESSES IN SERVICE					
Critical Compression					
Top of Beam	1.560	4.22	24.00	0%	
Bottom of Beam	2.683	4.39	24.00	0%	
Critical Tension					
Top of Beam	0.000	0.00	-6.30	0%	Class U member - not cracked
Bottom of Beam	0.000	0.00	-6.30	0%	Class U member - not cracked
STRESSES IN SERVICE (SUSTAINED LOADS ONLY)					
Critical Compression					
Top of Beam	1.560	4.22	18.00	0%	
Bottom of Beam	2.683	4.39	18.00	0%	

* Tensile stress limit given is for Class T (controlled cracking). Beyond this limit crack control is required.

	At Transfer	During Lifting	In Service
Modulus of Rupture, fr =	-3.30 MPa	-3.41 MPa	-3.94 MPa

Strength Required for Transfer, f'ci = 10.9 MPa (f'c specified = 28.0 MPa)
Strength Required for Initial Lifting, f'c = 10.9 MPa (f'c assumed = 30.0 MPa)

CRACK CONTROL
(+ve = compression, -ve = tension)

CRACK CONTROL STEEL AND SPACING

	Bottom of Beam	Top of Beam		
cc	0.0	0.0	mm	Clear concrete cover to steel closest to tension face
fs	0	0	MPa	Steel stress nearest to tension face (after decompression) for crack control
Max spacing	0.0	0.0	mm	Maximum centre-to-centre spacing of steel closest to tension face to control cracking

Beam not cracked, cracking is controlled, or crack depth is less than concrete cover.

DEFLECTION ESTIMATE AT ALL STAGES

Design Code Used: ACI 318-11 (customized)

A. Deflections at All Stages

Project: BUID Dissertation - Composite action of Hollow Core slab
Problem: HCS 150 non composite

(-ve = deflection down, +ve = camber up)

Location x m Column	Net Deflection: Net @ Transfer mm A	Net @ Erection mm B	Net @ Completion mm C	Net DL @ Final mm D	Net Total @ Final mm E	Change in Deflection: DL growth + LL mm E - C	LL alone mm E - D	Span/Deflection: DL growth + LL L / (E-C)	LL alone L / (E-D)
0.000	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0	0
0.250	0.5	1.1	1.1	0.1	0.1	-1.0	0.0	3220	0
0.562	1.1	2.2	2.3	0.2	0.2	-2.1	0.0	1497	0
0.874	1.5	3.1	3.1	0.1	0.1	-3.0	0.0	1042	0
1.186	1.8	3.6	3.7	0.0	0.0	-3.6	0.0	865	0
1.498	1.9	3.8	3.9	0.0	0.0	-3.9	0.0	806	0
1.560	1.9	3.8	3.9	0.0	0.0	-3.9	0.0	804	0
1.622	1.9	3.8	3.9	0.0	0.0	-3.9	0.0	806	0
1.810	1.8	3.7	3.8	0.0	0.0	-3.8	0.0	830	0
1.934	1.8	3.6	3.7	0.0	0.0	-3.6	0.0	865	0
2.246	1.5	3.1	3.1	0.1	0.1	-3.0	0.0	1042	0
2.558	1.1	2.2	2.3	0.2	0.2	-2.1	0.0	1497	0
2.870	0.5	1.1	1.1	0.1	0.1	-1.0	0.0	3220	0
3.120	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0	0

Col. A: Net deflection at transfer includes prestressing and beam weight on temporary supports.
Col. B: Net deflection at erection includes prestressing and all dead loads applied before the cast-in-place pour plus long-time deflection growth of the prestressing and beam weight up to erection
Col. C: Net deflection at completion of construction includes prestressing and all dead loads plus long-time deflection growth of the prestressing and dead load up to completion
Col. D: Net DL deflection at final includes prestressing, all dead loads, and sustained live loads, plus long-time deflection growth.
Col. E: Net total deflection at final includes prestressing, all dead loads, and all live loads, plus long-time deflection growth.

Deflection/camber is measured from the cast shape of the beam before release of prestressing.

Deflection growth is estimated by use of the PCI suggested multipliers - see the Deflection Multipliers report.

Span/Deflection Limits: DL growth + LL = L / 480 for non-structural attachments
L / 240 otherwise
LL alone = L / 360 for floors
L / 180 for roofs

SUPPORT ROTATION AND CHANGE OF LENGTH ESTIMATE AT ALL STAGES

Design Code Used: ACI 318-11 (customized)

B. Unrestrained Support Rotations at All Stages
(+ve = clockwise rotation)

Support Location Column	Net Rotation: Net @ Transfer degrees A	Net @ Erection degrees B	Net @ Completion degrees C	Net DL @ Final degrees D	Net Total @ Final degrees E	Change in Rotation: DL growth + LL degrees E - C	LL alone degrees E - D
Left	-0.1250	-0.2517	-0.2602	-0.0353	-0.0353	0.2250	0.0000
Right	0.1250	0.2517	0.2602	0.0353	0.0353	-0.2250	0.0000

C. Unrestrained Longitudinal Change of Length Due to Creep and Shrinkage
(-ve = shortening, +ve = elongation)

Elastic Shortening = -0.35 mm

	Total Change of Length (after elastic shortening): Erection mm B	Completion mm C	Final mm D	Difference in Change: to Compl. mm C - B	to Final mm D - C	to Final mm D - B
Creep	-0.32	-0.44	-0.67	-0.12	-0.23	-0.35
Shrink.	-0.93	-1.37	-1.73	-0.44	-0.37	-0.80
Total	-1.25	-1.81	-2.41	-0.55	-0.60	-1.15

FLEXURAL DESIGN CHECK

Design Code Used: ACI 318-11 (customized)
Concrete compressive stress-strain model used: PCA Parabola-Rectangle Curve

Modulus of Rupture of Precast Concrete, fr = 3.94 MPa (tension)

x m	Design Moment Mu t.m	Cracking Moment Mcr t.m	Minimum Required Strength t.m	Design Strength ØMn t.m	Depth in Compression c mm	Net Tensile Strain	Flexural Classication	Ø	Warnings & Notes
0.000	0.00	1.56	0.00	0.00	0.4	0.9570	Tension	0.75	
0.250	0.66	3.11	3.73	1.67	6.3	0.0544	Tension	0.75	B
0.562	1.31	4.21	2.63	3.09	11.6	0.0281	Tension	0.76	
0.874	1.80	4.22	3.59	3.91	13.8	0.0231	Tension	0.80	
1.186	2.10	4.23	4.20	4.79	16.5	0.0189	Tension	0.84	
1.498	2.22	4.23	4.45	5.71	19.1	0.0159	Tension	0.88	
1.560	2.23	4.23	4.45	6.12	20.2	0.0148	Tension	0.89	
1.622	2.22	4.23	4.45	5.71	19.1	0.0159	Tension	0.88	
1.810	2.17	4.23	4.34	5.15	17.5	0.0176	Tension	0.86	
1.934	2.10	4.23	4.20	4.79	16.5	0.0189	Tension	0.84	
2.246	1.80	4.22	3.59	3.91	13.8	0.0231	Tension	0.80	
2.558	1.31	4.21	2.63	3.09	11.6	0.0281	Tension	0.76	
2.870	0.66	3.11	3.73	1.67	6.3	0.0544	Tension	0.75	B
3.120	0.00	1.56	0.00	0.00	0.4	0.9570	Tension	0.75	
Points of Maximum and Minimum Factored Moment									
1.560	2.23	4.23	4.45	6.12	20.2	0.0148	Tension	0.89	
0.000	0.00	1.40	0.00	0.00	0.4	0.2370	Tension	0.75	
Points of Maximum Ratio of Factored Moment to Design Strength									
0.874	1.80	4.22	3.59	3.91	13.8	0.0231	Tension	0.80	
0.000	0.00	1.40	0.00	0.00	0.4	0.2370	Tension	0.75	

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Problem: HCS 150 non composite

Points of Maximum Ratio of Minimum Strength to Design Strength

0.125	0.34	2.35	2.83	0.87	3.2	0.1086	Tension	0.75	B
0.000	0.00	1.40	0.00	0.00	0.4	0.2370	Tension	0.75	

Warnings & Notes
B - WARNING, ØMn<1.2Mcr and ØMn<2.0Mu or ØVn<2.0Vu, minimum reinforcement requirement not met [ACI 318-11::18.8.2].
Extent: x = 0.125 to 0.250 m, 2.870 to 2.995 m

SHEAR DESIGN CHECK

Design Code Used: ACI 318-11 (customized)

x m	Design Shear Vu kN	Prestress Component Vp kN	Concrete Strength ØVc kN	Core Fill Strength ØVc (core) kN	Required Stirrups ØVs kN	Strength Provided Stirrups ØVs kN	Total ØVn kN	Warnings & Notes
0.000	26.12	0.00	27.04	0.00	0.00	0.00	27.04	3
0.250	23.52	0.00	45.98	0.00	0.00	0.00	45.98	
0.562	17.92	0.00	45.82	0.00	0.00	0.00	45.82	
0.874	12.32	0.00	26.12	0.00	0.00	0.00	26.12	
1.186	6.72	0.00	17.11	0.00	0.00	0.00	17.11	
1.498	1.12	0.00	17.11	0.00	0.00	0.00	17.11	
1.560	0.00	0.00	17.11	0.00	0.00	0.00	17.11	
1.560	0.00	0.00	-17.11	0.00	0.00	0.00	-17.11	
1.622	-1.12	0.00	-17.11	0.00	0.00	0.00	-17.11	
1.810	-4.48	0.00	-17.11	0.00	0.00	0.00	-17.11	
1.934	-6.72	0.00	-17.11	0.00	0.00	0.00	-17.11	
2.246	-12.32	0.00	-26.12	0.00	0.00	0.00	-26.12	
2.558	-17.92	0.00	-45.82	0.00	0.00	0.00	-45.82	
2.870	-23.52	0.00	-45.98	0.00	0.00	0.00	-45.98	
3.120	-26.12	0.00	-27.04	0.00	0.00	0.00	-27.04	3

Warnings & Notes
3 - Note, design shear force at critical section near support used [ACI 318-11::11.1.3].

SHEAR TRANSVERSE REINFORCING DESIGN CHECK

Design Code Used: ACI 318-11 (customized)

x m	Shear Steel Grade fy MPa	Shear Steel Required Av/s mm^2/m	Shear Steel Provided Av/s mm^2/m	Stirrup Provided Av mm^2	Stirrup Spacing Provided s mm	Stirrup Spacing Max. Allow s mm	Warnings & Notes
0.000	400	0	0	400.00	0.0	112.5	4
0.250	400	0	0	400.00	0.0	112.5	
0.562	400	0	0	400.00	0.0	112.5	
0.874	400	0	0	400.00	0.0	112.5	
1.186	400	0	0	400.00	0.0	112.5	
1.498	400	0	0	400.00	0.0	112.5	
1.560	400	0	0	400.00	0.0	112.5	
1.560	400	0	0	400.00	0.0	112.5	
1.622	400	0	0	400.00	0.0	112.5	
1.810	400	0	0	400.00	0.0	112.5	
1.934	400	0	0	400.00	0.0	112.5	
2.246	400	0	0	400.00	0.0	112.5	
2.558	400	0	0	400.00	0.0	112.5	
2.870	400	0	0	400.00	0.0	112.5	
3.120	400	0	0	400.00	0.0	112.5	4

Warnings & Notes
4 - Note, design shear force at critical section near support used [ACI 318-11::11.1.3].
Note, shear steel requirements for pre-tension bursting have NOT been included (calculation option S8).
Note, additional long. steel in compression side of section has been reduced [ACI 318-11::11.5.3.9].
* Portion of the total stirrup area required to resist torsional shear flow (one leg around periphery).
** The allowable reduction in Al within the flexural compression zone.

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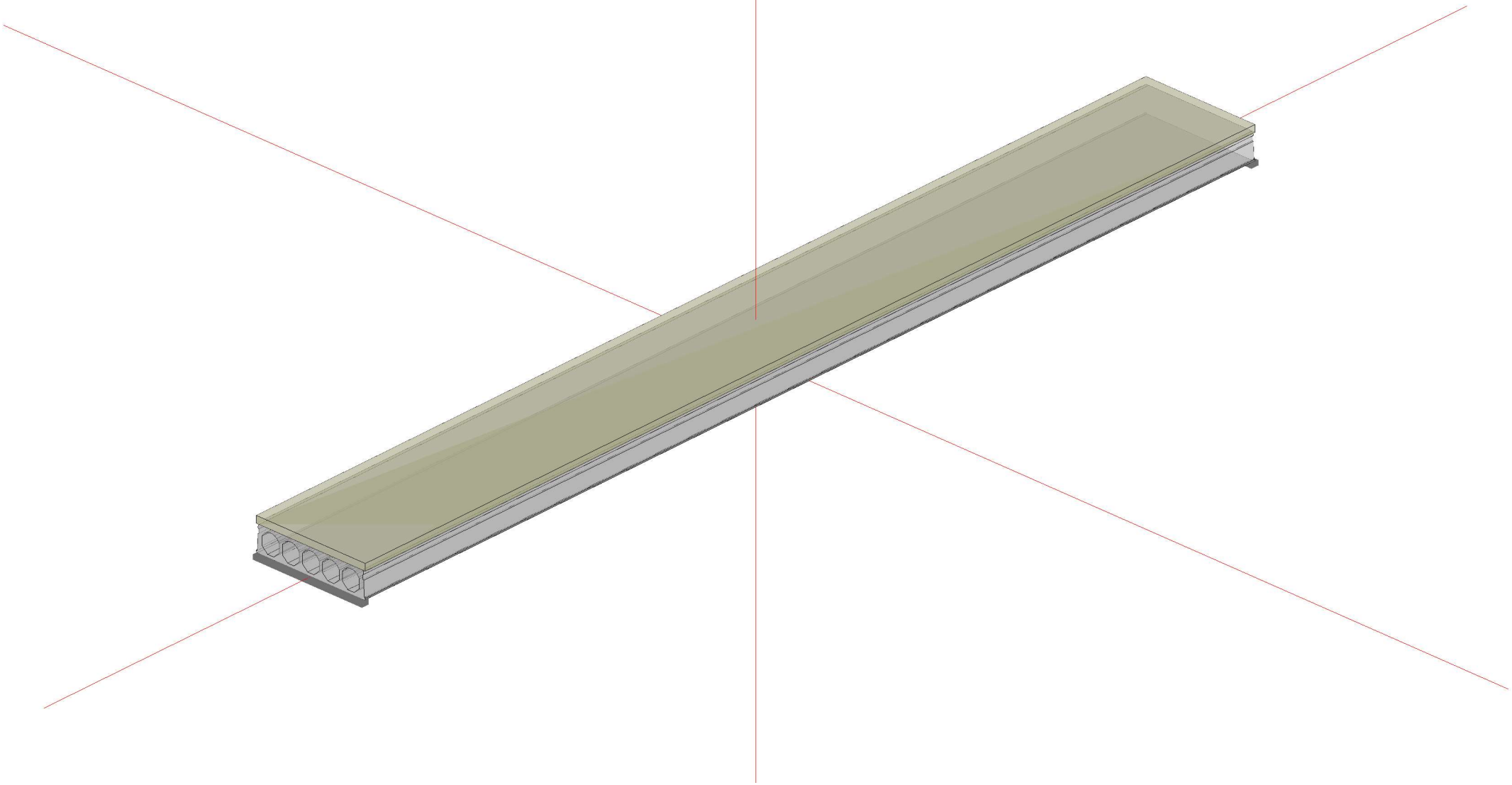
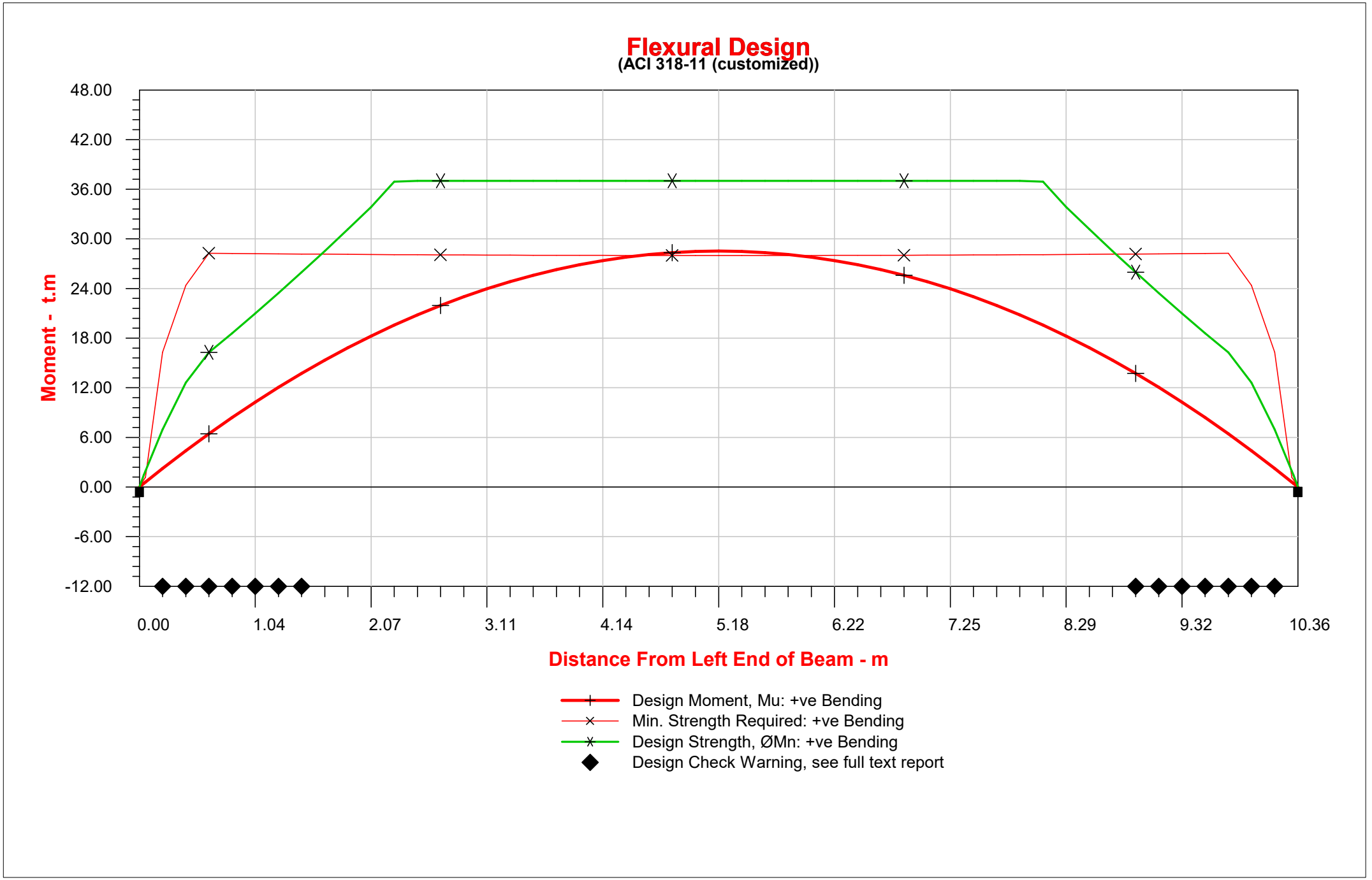
Problem: HCS 265 composite section

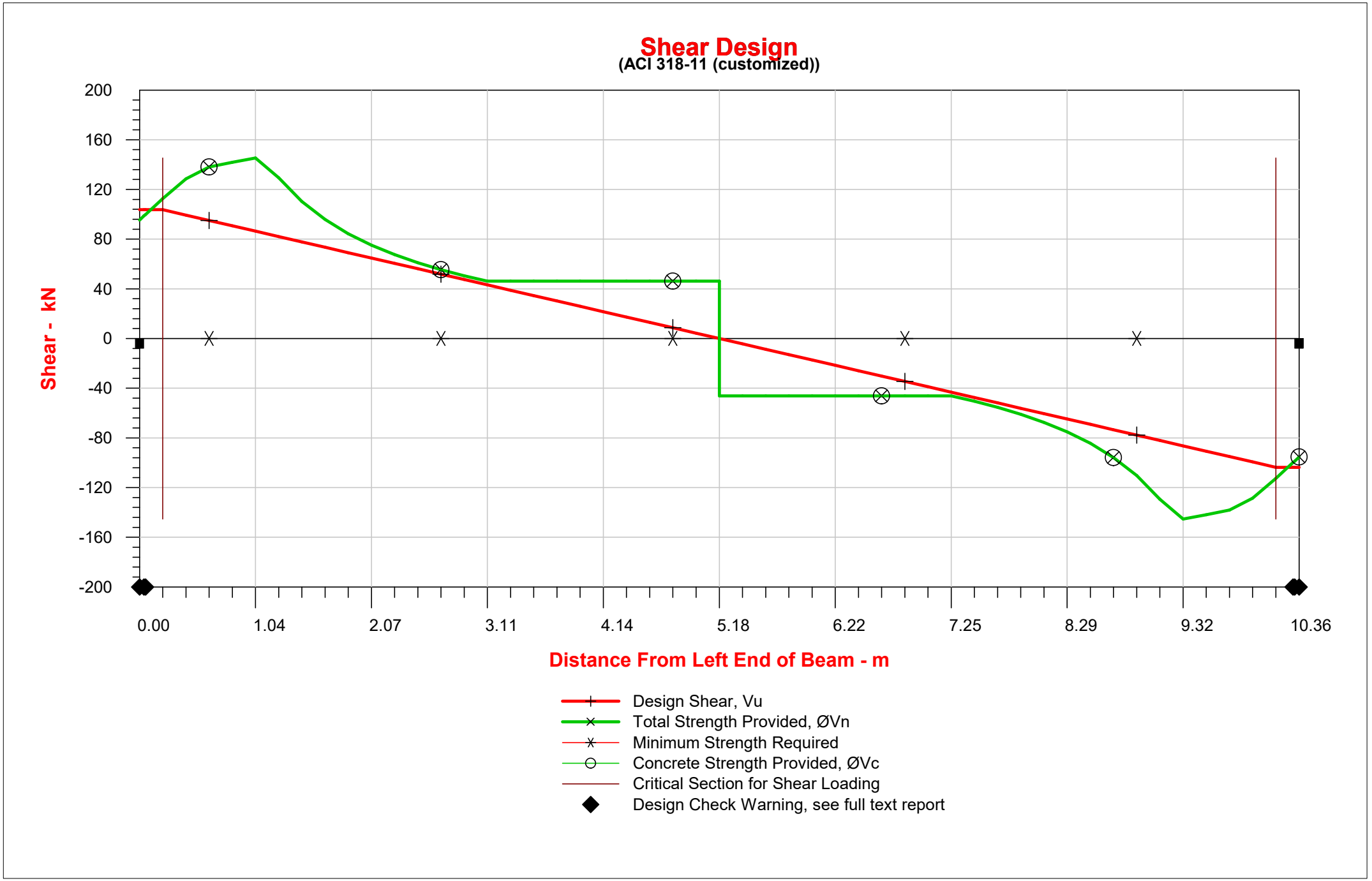
Hollow core slab 265mm considered as composite with 70mm structural screed.



Project: BUID Dissertation - Composite action of Hollow Core slab
Problem: HCS 265 composite section



Project: BUID Dissertation - Composite action of Hollow Core slab
Problem: HCS 265 composite section



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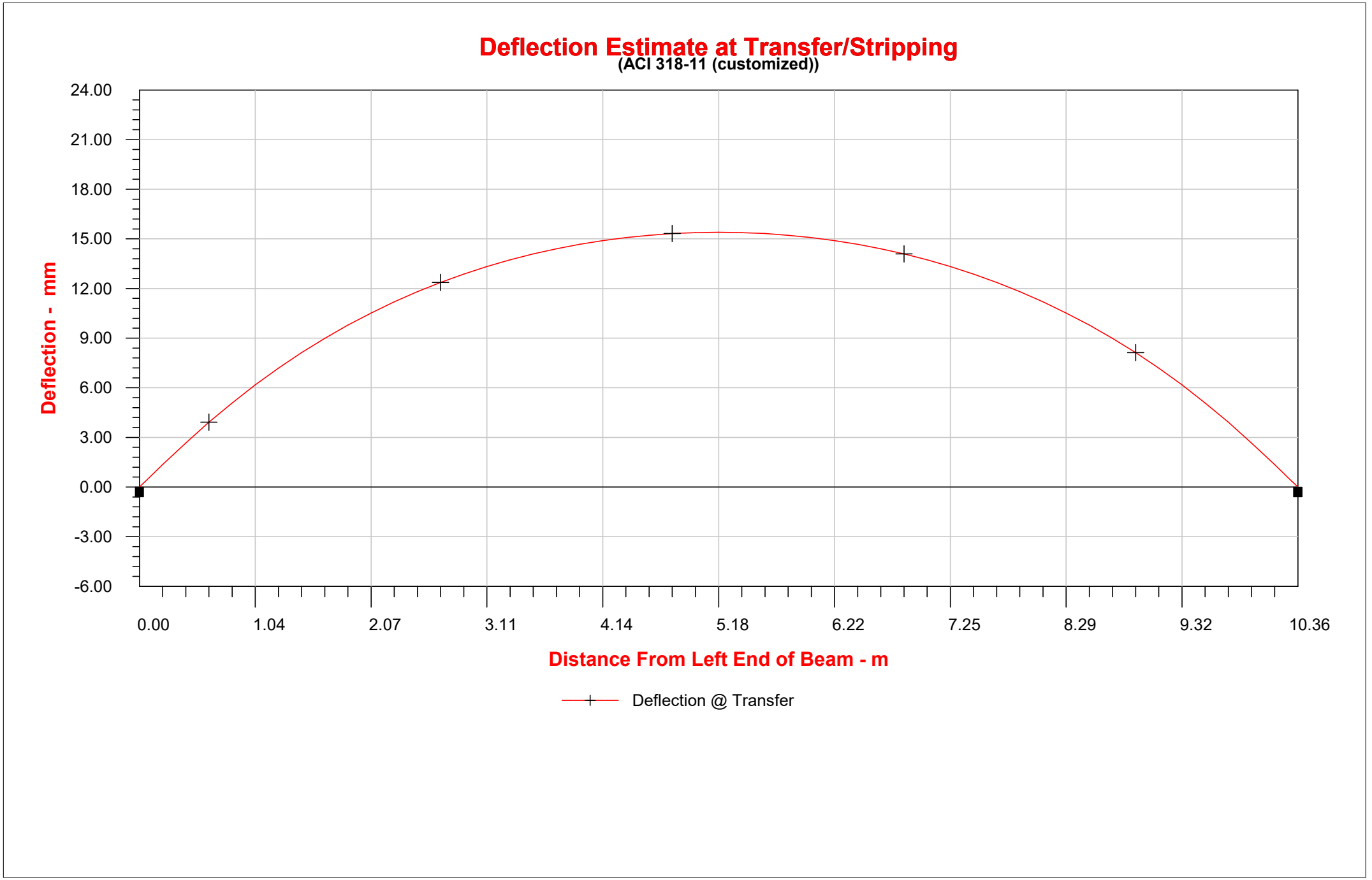
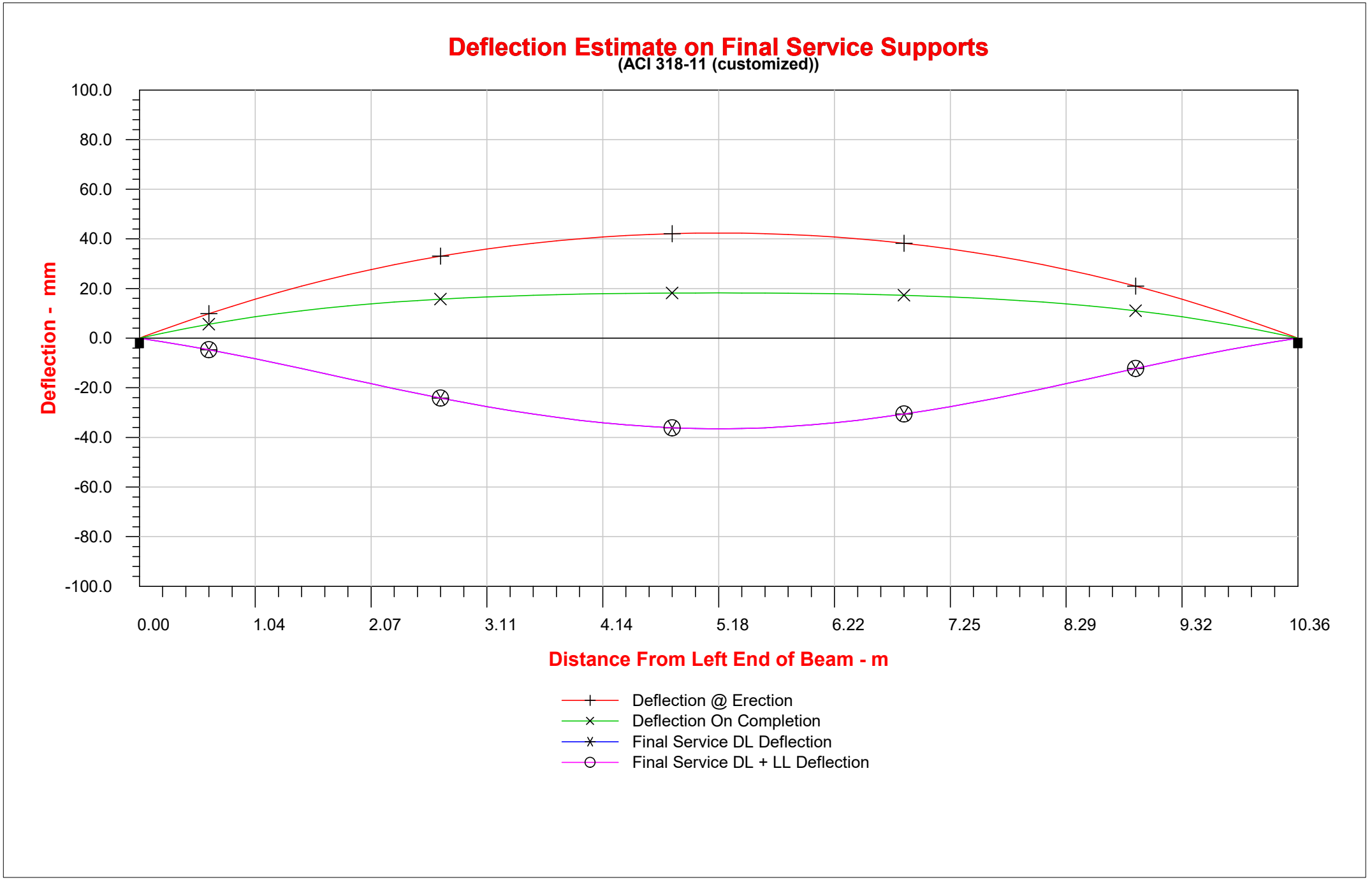
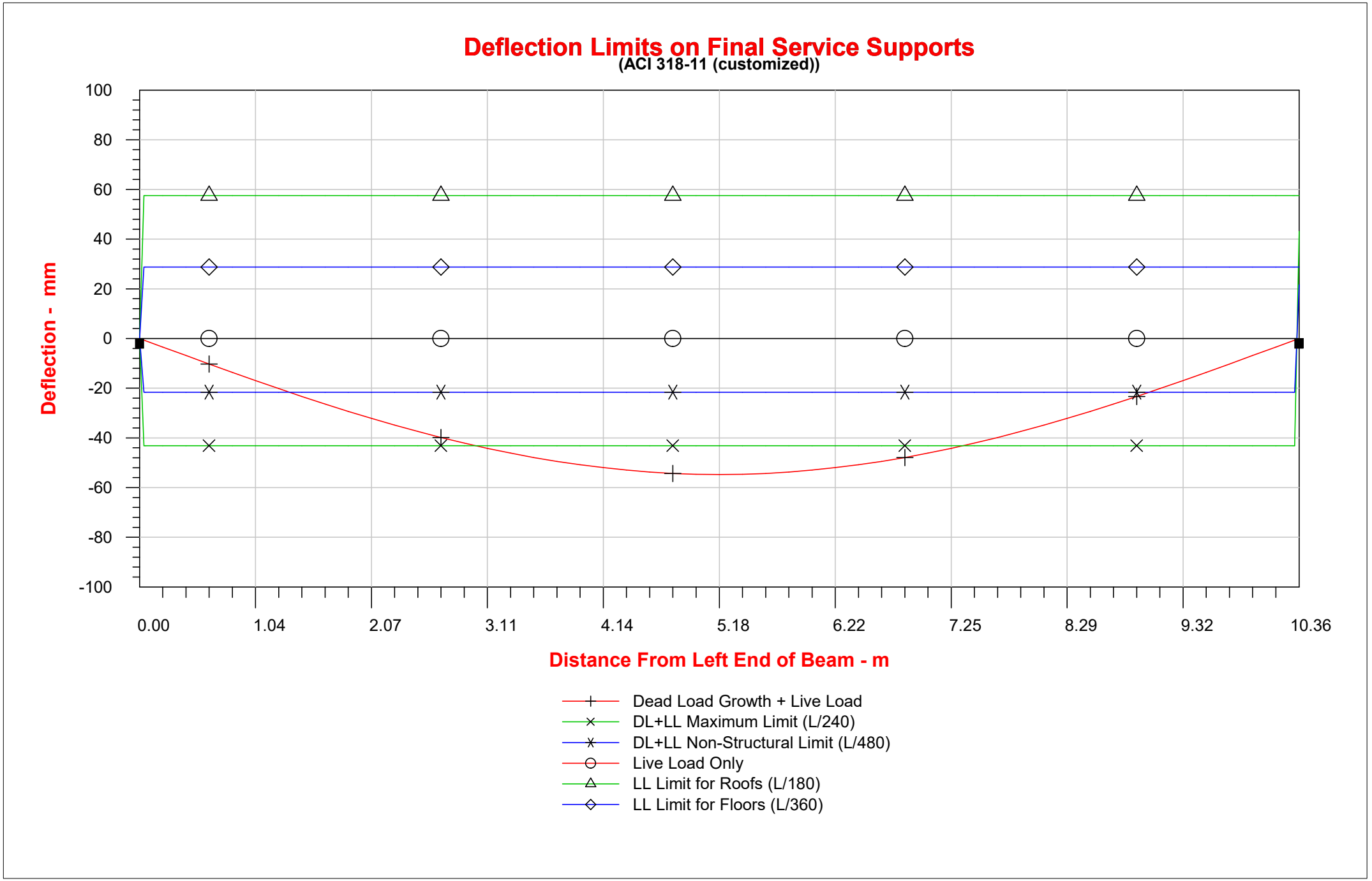
Problem: HCS 265 composite section



Project: BUID Dissertation - Composite action of Hollow Core slab
Problem: HCS 265 composite section



Project: BUID Dissertation - Composite action of Hollow Core slab
Problem: HCS 265 composite section



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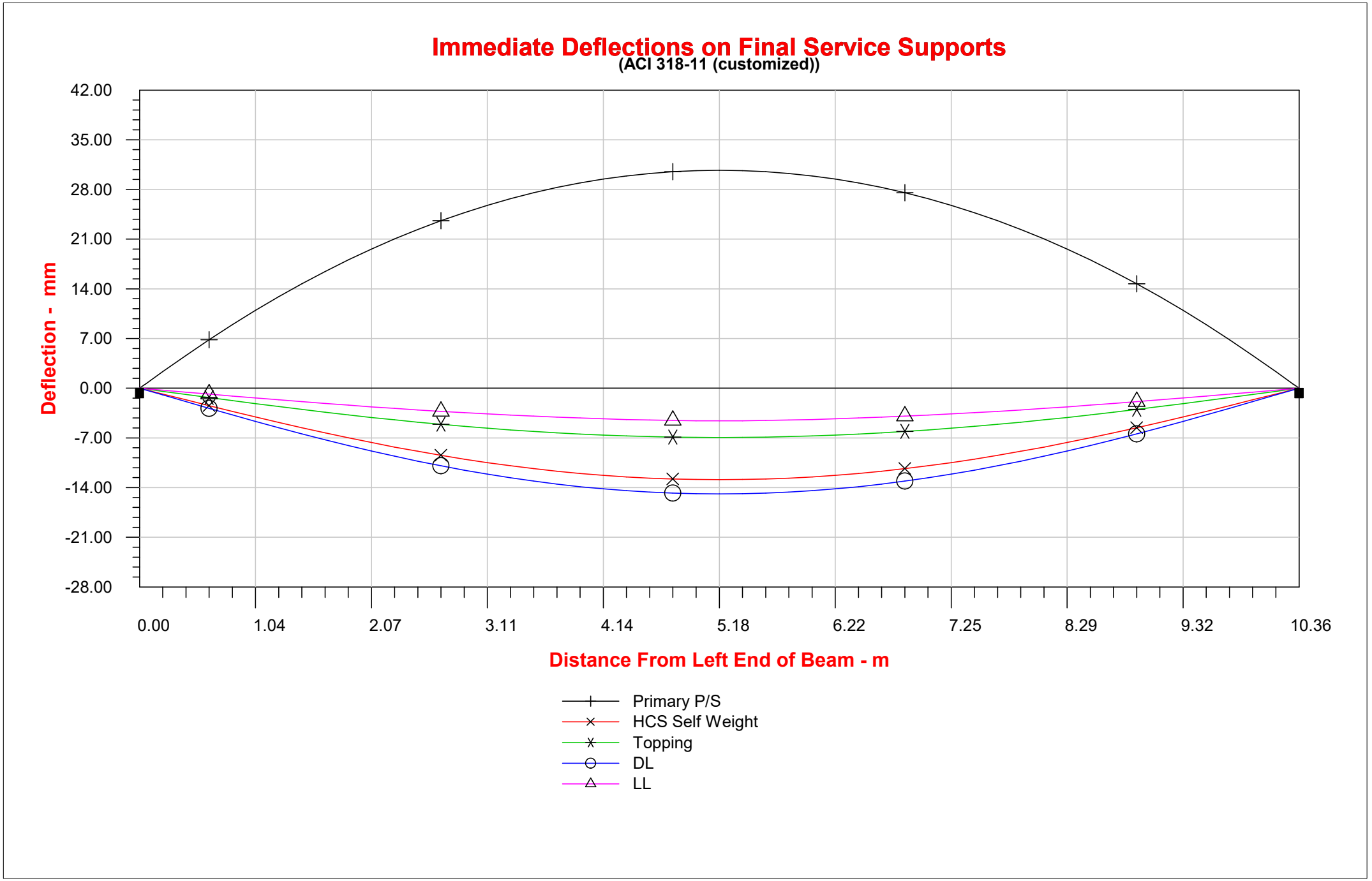
Problem: HCS 265 composite section



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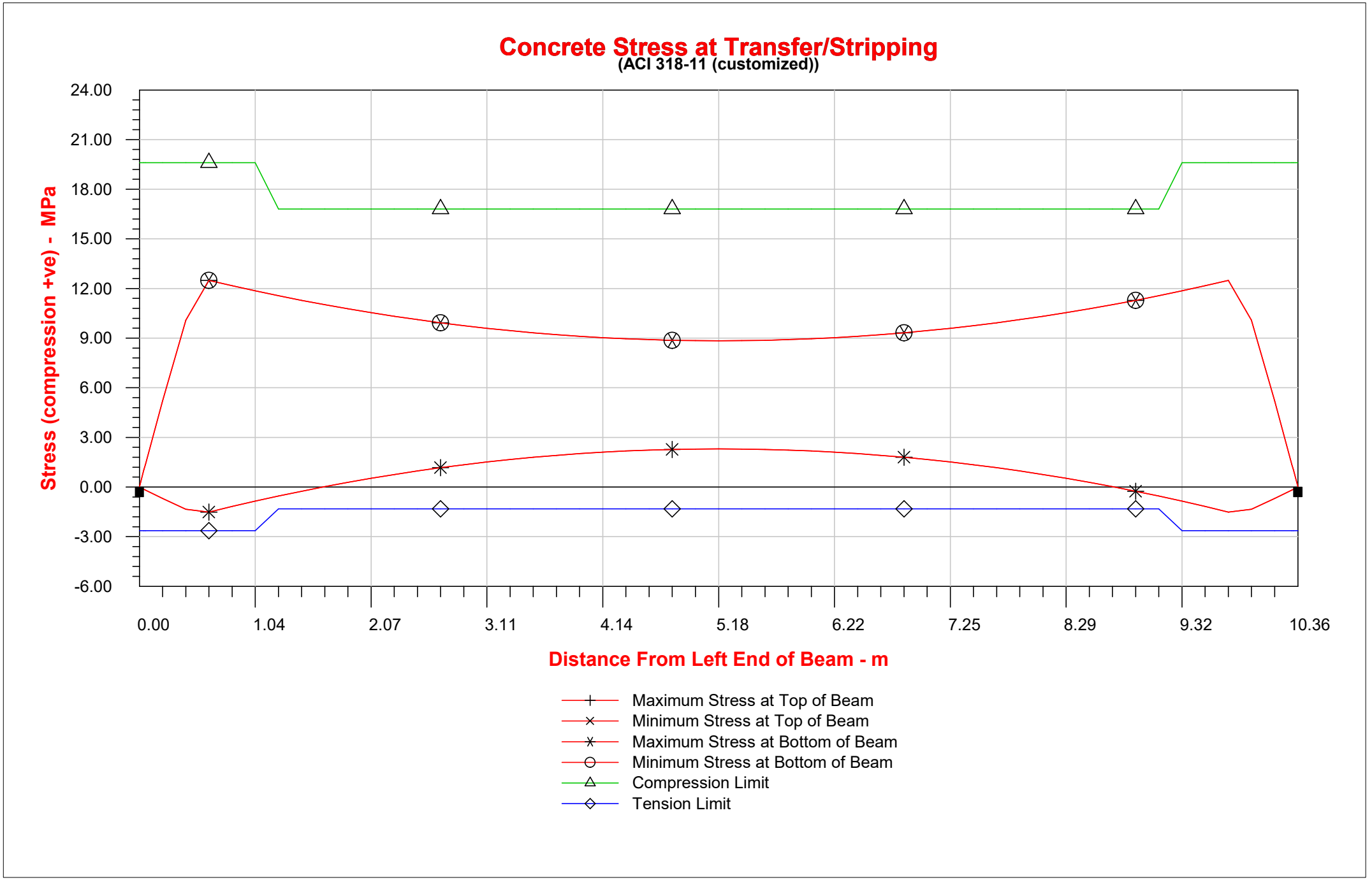
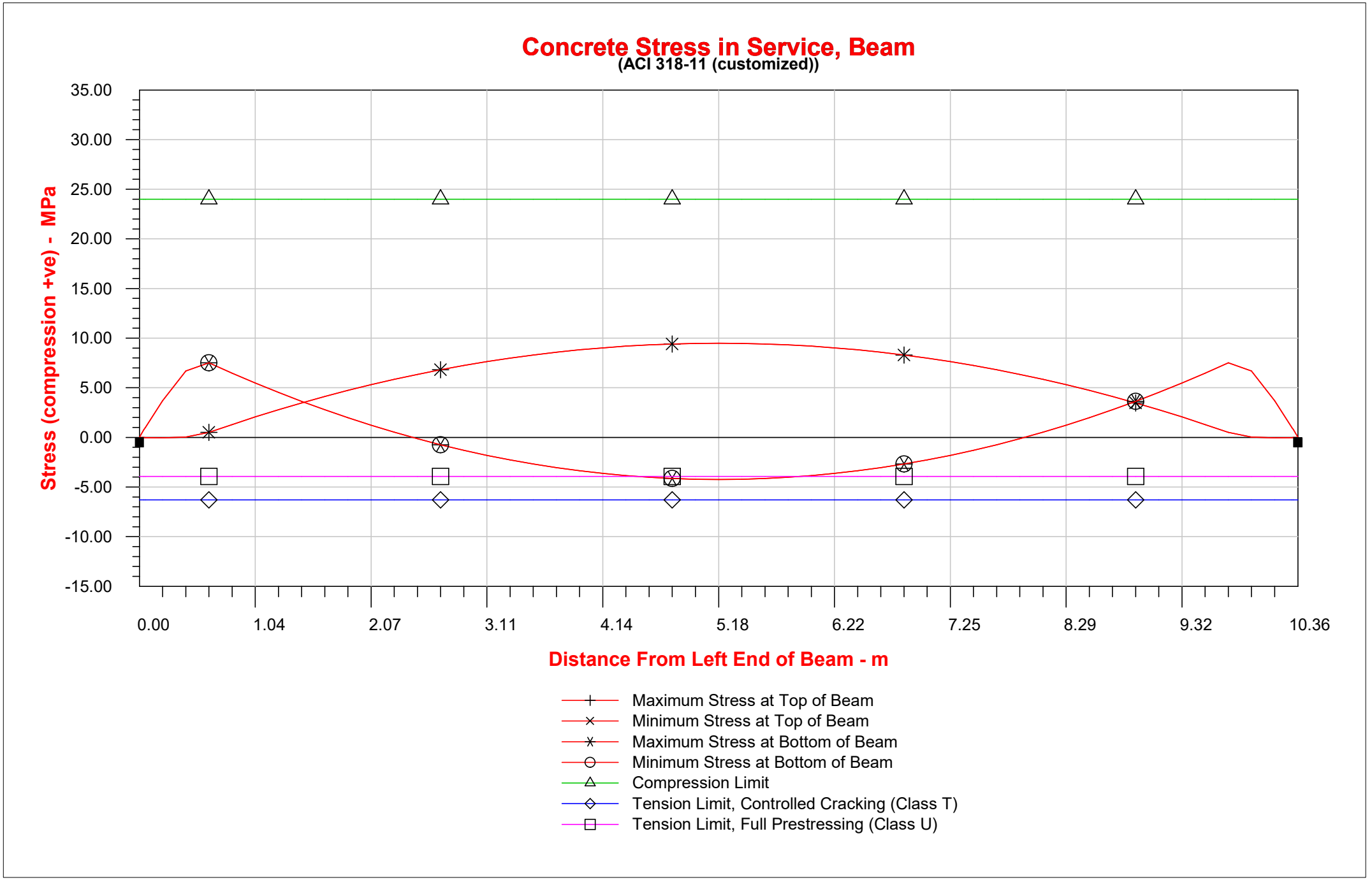
Problem: HCS 265 composite section



Project: BUID Dissertation - Composite action of Hollow Core slab
Problem: HCS 265 composite section



Project: BUID Dissertation - Composite action of Hollow Core slab
Problem: HCS 265 composite section

SUMMARY REPORT

Design Code Used: ACI 318-11 (customized)

NON-DEFAULT OPTION SETTINGS

** OFF ** G2: Use PCI Standard Design Practice, TR-7-05 (ACI codes only)
** ON ** P1: Vary user defined losses along beam
** OFF ** F7: Reduce ϕ in the development length of strands (CSA A23.3 only)
** OFF ** F8: Use a rectangular stress block at concrete ultimate strain
** ON ** S10: Use the ultimate section capacity for horizontal shear (moment region check)
** OFF ** D3: Have Concise Beam calculate the long-term deflection multipliers for prestressed Beams

CONCRETE MATERIAL PROPERTIES

	Precast Beam			Cast-in-Place Pour		
Concrete Density	Wt	=	2400 kg/m^3	Wt	=	2400 kg/m^3
Compressive Strength	f'c	=	40.0 MPa	f'c	=	28.0 MPa
Modulus of Elasticity	Ec	=	31783 MPa	Ec	=	26591 MPa
Strength at Transfer	f'c	=	28.0 MPa			
Modulus of Elast. at Transfer	Ec	=	26591 MPa			
Strength at Lifting	f'c	=	30.0 MPa			
Modulus of Elast. at Lifting	Ec	=	26621 MPa			

Cement Content = 410 kg/m^3
Air Content = 5.00 %
Slump = 50.0 mm
Aggregate Mix = 0.40 (fine to total aggregate ratio)
Aggregate Size = 20.0 mm
Basic Shrinkage Strain = 780.000E-6

Construction Schedule
Age at Transfer = 0.75 days
Age at Erection = 40 days
Age at Cast-in-Place Pour = 50 days
Age Cast-in-Place is Composite = 53 days
Age Construction is Complete = 143 days

Curing Method = Moist
Relative Humidity in Service = 70 %
Ambient Temperature in Service = 20 deg C

PRECAST BEAM LAYOUT

Segment/Length			Section Identification			Offset	
No	From m	To m	Length m	Folder Name	Section Name	Section Type	Z mm	Y mm
1	0.000	10.360	10.360	Standard HC	HCS265	Hollowcore	0.0	0.0

CAST-IN-PLACE POUR LAYOUT

Segment/Length				Slab/Topping Parameters			Haunch Paramaters			Vertical	Composite Interface		Total Width	
No	From m	To m	Length m	Thick. mm	Width mm	Offset mm	Thick. mm	Width mm	Offset mm	Offset mm	Width mm	Offset mm	Actual mm	Effective mm
1	0.000	10.360	10.360	70.0	1200.0	0.0	0.0	0.0	0.0	0.0	1140.0	0.0	1200.0	1200.0

Beam is UNSHORED during the cast-in-place pour and superimposed dead load.

* Long offset from left end of beam. Transverse offset from top of precast to top of opening
for horizontal orientation or from center of precast to center of opening for vertical orientation.

Span Length at Transfer = 10.360 m, Centre of Supports, Left @ 0.000 m, Right @ 10.360 m
Span Length during Lift = 10.360 m, Centre of Supports, Left @ 0.000 m, Right @ 10.360 m Loop Height = 0.0 mm
Span Length in Service = 10.360 m, Centre of Supports, Left @ 0.000 m, Right @ 10.360 m
Total Beam Length = 10.360 m, Bearing Length, Left = 80.0 mm, Right = 80.0 mm

First flexural frequency of beam is approximately 3.87 Hz

GROSS PRECAST SECTION PROPERTIES (NON-COMPOSITE)
(based on Ec of the precast beam - transformed area of rebar and strand NOT included)

Seg. No.	Section Properties A mm^2	I mm^4	yb mm	Section Height mm	Section Width mm	Shear Width mm	Volume / Surface mm	Section Moduli Sb mm^3	St mm^3
1	151029	1.384E+9	133.0	265.0	1200.0	234.0	52.00	-10.405E+6	10.484E+6

GROSS COMPOSITE SECTION PROPERTIES
(based on Ec of the precast beam - transformed area of rebar and strand NOT included)

Seg. No.	Section Properties Ac mm^2	Ic mm^4	yb mm	Section Height mm	Section Moduli Sb mm^3	St mm^3	Sbc mm^3	Stc mm^3
1	221307	2.750E+9	186.0	335.0	-14.783E+6	34.826E+6	34.826E+6	18.461E+6

Note: Sb & St = bottom and top of the precast beam, Sbc & Stc = bottom and top of the cast-in-place pour.

UNCRACKED SECTION PROPERTIES SUMMARY

	Net Precast Section at Transfer (based on Eci) (include rebar,deduct strand)			Transformed Precast Section at Transfer (based on Eci) (include rebar and strand)			Transformed Precast Section in Service (based on Ec) (include rebar and strand)			Transformed Composite Section in Service (based on Ec) (include rebar and strand)		
x m	A mm^2	I mm^4	yb mm	A mm^2	I mm^4	yb mm	A mm^2	I mm^4	yb mm	Ac mm^2	Ic mm^4	ybc mm
0.000	150239	1.375E+9	133.5	151034	1.384E+9	133.0	151033	1.384E+9	133.0	221311	2.750E+9	186.0
0.622	150239	1.375E+9	133.5	156178	1.437E+9	129.6	155208	1.427E+9	130.2	225486	2.850E+9	183.1
1.658	150239	1.375E+9	133.5	156178	1.437E+9	129.6	155208	1.427E+9	130.2	225486	2.850E+9	183.1
2.694	150239	1.375E+9	133.5	156178	1.437E+9	129.6	155208	1.427E+9	130.2	225486	2.850E+9	183.1
3.730	150239	1.375E+9	133.5	156178	1.437E+9	129.6	155208	1.427E+9	130.2	225486	2.850E+9	183.1

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4.766	150239	1.375E+9	133.5	156178	1.437E+9	129.6	155208	1.427E+9	130.2	225486	2.850E+9	183.1
5.180	150239	1.375E+9	133.5	156178	1.437E+9	129.6	155208	1.427E+9	130.2	225486	2.850E+9	183.1
5.594	150239	1.375E+9	133.5	156178	1.437E+9	129.6	155208	1.427E+9	130.2	225486	2.850E+9	183.1
5.802	150239	1.375E+9	133.5	156178	1.437E+9	129.6	155208	1.427E+9	130.2	225486	2.850E+9	183.1
6.630	150239	1.375E+9	133.5	156178	1.437E+9	129.6	155208	1.427E+9	130.2	225486	2.850E+9	183.1
7.666	150239	1.375E+9	133.5	156178	1.437E+9	129.6	155208	1.427E+9	130.2	225486	2.850E+9	183.1
8.702	150239	1.375E+9	133.5	156178	1.437E+9	129.6	155208	1.427E+9	130.2	225486	2.850E+9	183.1
9.738	150239	1.375E+9	133.5	156178	1.437E+9	129.6	155208	1.427E+9	130.2	225486	2.850E+9	183.1
10.360	150239	1.375E+9	133.5	151034	1.384E+9	133.0	151033	1.384E+9	133.0	221311	2.750E+9	186.0

These section properties can used to calculate uncracked concrete stresses using the following guidelines.

Net Precast Section at Transfer properties are used with the initial prestress after transfer (after elastic shortening loss).
Transformed Precast Section at Transfer properties are used with the precast beam self-weight.
Transformed Precast Section in Service properties are used with external loads applied to the non-composite precast beam.
Transformed Composite Section in Service properties are used with external loads applied to the composite precast beam.

PRESTRESSING STEEL TENDONS

ID	Qty	Grade MPa	Type *	Strand Size	Offsets x m	Offsets y mm	End Offset & Type Left ** m	End Offset & Type Right ** m	Tendon Area mm^2	Jacking Force Pj kN	Jacking Force %fpu
1	8.000	1860	LRS	13 (1/2")	0.000 10.360	30.0 30.0	0.000 B	0.000 B	789.60	881.19	0.60

note: * Type = LRS - Low-Relaxation Strand, SRS - Stress-Relieved Strand, PB - Plain Bar,
DB - Deformed Bar, SW - Single Wire
** End Types = B - Fully Bonded (B), D - Debonded (D), C - Cut (C), F - Full Develop (F) (fully developed)

Calculated Losses: Initial = 7.9%, Final = 12.2%
Maximum Total Prestress Forces: Pj(jacking) = 881.19 kN,
Pi(transfer) = 811.55 kN,
Pe(effective) = 773.94 kN @ x = 5.180 m,

See the "Development Length" text report for details of the strand transfer and development lengths

TRANSVERSE SHEAR STEEL

Shear Stirrups

From m	To m	Grade MPa	Size	# of Legs	Total Area mm^2	Spacing mm
0.000	10.360	400	15M	2	400.0	0.0

Interface Shear Ties

From m	To m	Grade MPa	Size	# of Legs	Total Area mm^2	Spacing mm
0.000	10.360	400	15M	0	0.0	0.0

APPLIED LOADS

Load Group & Type	Stages Applied & Distribution	Load Details (left to right)
HCS Self Weight D: DL, General	Transfer to Final Service No Load Distribution	HCS Self Weight- Area: 3.25 kN/m^2 full length, 1.2 m wide
Topping D: DL, General	CIP Placement to Final Service No Load Distribution	Topping- Area: 1.75 kN/m^2 full length, 1.2 m wide
DL D: DL, General	Completion to Final Service No Load Distribution	SDL- Area: 7.5 kN/m^2 full length, 1.2 m wide
LL L: LL, General	Completion to Final Service No Load Distribution	LL- Area: 2 kN/m^2 full length, 1.2 m wide

Some load groups are generated automatically by Concise Beam.

LOAD COMBINATIONS

Serviceability (SLS) & Fatigue (FLS) Limit State Combinations (used individually)
SLS Stress : 1.00P + 1.00D + 1.00F + 1.00T + 1.00L + 1.00L1 + 1.00Lr + 1.00R + 1.00S + 1.00Ws + 0.60Wu
SLS Deflect : 1.00P + 1.00D + 1.00F + 1.00T + 1.00L + 1.00L1 + 1.00Lr + 1.00R + 1.00S
FLS Fatigue : 1.00P + 1.00D + 1.00F + 1.00L + 1.00L1 + 1.00Lr

Ultimate (Strength) Limit State (ULS) Combinations (searched collectively to obtain envelope)
1: Case 1 : 1.15D + 1.50L + 0.40Lr
2: Case 2 : 1.15D + 0.90L + 1.50Lr
3: Case 3 : 1.30D

COMBINED ANALYSIS IN SERVICE (external loads only)

Station	SLS (stress) Load Combination Moment Sustained	SLS (stress) Load Combination Moment Total Load		ULS Load Envelopes Shear Total Load		ULS Load Envelopes Shear Govern. Combo.		ULS Load Envelopes Moment Total Load		ULS Load Envelopes Moment Govern. Combo.	
x m	t.m	t.m min	t.m max	kN min	kN max	min	max	t.m min	t.m max	min	max
0.000	0.00	0.00	0.00	100.54	108.00	2	1	0.00	0.00	1	1
0.622	5.37	5.37	5.37	88.48	95.04	2	1	5.99	6.44	2	1

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1.658	12.80	12.80	12.80	68.37	73.44	2	1	14.28	15.33	2	1
2.694	18.32	18.32	18.32	48.26	51.84	2	1	20.44	21.95	2	1
3.730	21.94	21.94	21.94	28.15	30.24	2	1	24.47	26.29	2	1
4.766	23.65	23.65	23.65	8.04	8.64	2	1	26.38	28.34	2	1
5.180	23.80	23.80	23.80	0.00	0.00	1	1	26.55	28.52	2	1
5.594	23.65	23.65	23.65	-8.64	-8.04	1	2	26.38	28.34	2	1
5.802	23.46	23.46	23.46	-12.96	-12.07	1	2	26.17	28.11	2	1
6.630	21.94	21.94	21.94	-30.24	-28.15	1	2	24.47	26.29	2	1
7.666	18.32	18.32	18.32	-51.84	-48.26	1	2	20.44	21.95	2	1
8.702	12.80	12.80	12.80	-73.44	-68.37	1	2	14.28	15.33	2	1
9.738	5.37	5.37	5.37	-95.04	-88.48	1	2	5.99	6.44	2	1
10.360	0.00	0.00	0.00	-108.00	-100.54	1	2	0.00	0.00	1	1

COMBINED SUPPORT REACTIONS, ALL STAGES
(+ve = upwards, counter-clockwise)

Unfactored Load Group Effects

Load Group	Initial Lifting Left Vertical kN	Initial Lifting Right Vertical kN	Erection Lifting Left Vertical kN	Erection Lifting Right Vertical kN	During CIP Pour Left Vertical kN	During CIP Pour Right Vertical kN	In Service Left Vertical kN	In Service Left Torsion t.m	In Service Right Vertical kN	In Service Right Torsion t.m
HCS Self Wei	20.20	20.20	20.20	20.20	20.20	20.20	20.20	0.00	20.20	0.00
Topping					10.88	10.88	10.88	0.00	10.88	0.00
DL							46.62	0.00	46.62	0.00
LL							12.43	0.00	12.43	0.00

Load Envelope Effects

Load Envelope	Initial Lifting Left Vertical kN	Initial Lifting Right Vertical kN	Erection Lifting Left Vertical kN	Erection Lifting Right Vertical kN	During CIP Pour Left Vertical kN	During CIP Pour Right Vertical kN	In Service Left Vertical[*] kN	In Service Left Torsion[*] t.m	In Service Right Vertical[*] kN	In Service Right Torsion[*] t.m
SLS DL							77.70	0.00	77.70	0.00
SLS Sustain							90.13	0.00	90.13	0.00
SLS Minimum	20.20	20.20	20.20	20.20	31.08	31.08	90.13	0.00	90.13	0.00
SLS Maximum	20.20	20.20	20.20	20.20	31.08	31.08	90.13	0.00	90.13	0.00
ULS Minimum							100.54 [2]	0.00 [1]	100.54 [2]	0.00 [1]
ULS Maximum							108.00 [1]	0.00 [1]	108.00 [1]	0.00 [1]

|* Governing ULS Load Combination (below)

CONCRETE STRESS RESULTS (UNCRACKED ANALYSIS)
(+ve = compression, -ve = tension)

Location	x m	Stress MPa	Limit * MPa	Overstress Notice	
STRESSES AT TRANSFER					
Critical Compression					
Top of Beam	5.180	2.30	16.80	0%	
Bottom of Beam	1.243	11.57	16.80	0%	
					Longitudinal Tensile Rebar Needed (mm^2)
Critical Tension					Required Provided Additional
Top of Beam	0.622	-1.52	-2.64	0%	
Bottom of Beam	0.000	0.01	-2.64	0%	
STRESSES DURING INITIAL LIFTING					
Critical Compression					
Top of Beam	5.180	2.30	18.00	0%	
Bottom of Beam	1.243	11.57	18.00	0%	
					Longitudinal Tensile Rebar Needed (mm^2)
Critical Tension					Required Provided Additional
Top of Beam	0.622	-1.52	-2.73	0%	
Bottom of Beam	0.000	0.01	-2.73	0%	
STRESSES DURING ERECTION LIFTING					
Critical Compression					
Top of Beam	5.180	2.37	24.00	0%	
Bottom of Beam	1.243	10.65	24.00	0%	
					Longitudinal Tensile Rebar Needed (mm^2)
Critical Tension					Required Provided Additional
Top of Beam	0.622	-1.30	-3.15	0%	
Bottom of Beam	0.000	0.01	-3.15	0%	
STRESSES DURING CAST-IN-PLACE POUR					
Critical Compression					
Top of Beam	5.180	5.03	24.00	0%	
Bottom of Beam	0.622	10.82	24.00	0%	
Critical Tension					
Top of Beam	9.946	-0.79	-3.94	0%	
Bottom of Beam	0.000	0.01	-3.94	0%	
STRESSES IN SERVICE					
Critical Compression					
Top of Beam	5.180	9.49	24.00	0%	
Bottom of Beam	0.622	7.52	24.00	0%	
Top of CIP Pour	5.180	6.82	16.80	0%	
Critical Tension					
Top of Beam	10.153	-0.04	-6.30	0%	Class U member - not cracked
Bottom of Beam	5.180	-4.24	-6.30	0%	Class T member - cracking controlled
Top of CIP Pour	0.000	0.00	-3.30	0%	
STRESSES IN SERVICE (SUSTAINED LOADS ONLY)					
Critical Compression					
Top of Beam	5.180	9.49	18.00	0%	
Bottom of Beam	0.622	7.52	18.00	0%	

Project: BUID Dissertation - Composite action of Hollow Core slab
Problem: HCS 265 composite section

* Tensile stress limit given is for Class T (controlled cracking). Beyond this limit crack control is required.
  Tensile stress limit given for the cast-in-place pour is the flexural cracking strength of the concrete.

	At Transfer	During Lifting	In Service
Modulus of Rupture, fr =	-3.30 MPa	-3.41 MPa	-3.94 MPa
Strength Required for Transfer, f'ci =		19.3 MPa	(f'c specified = 28.0 MPa)
Strength Required for Initial Lifting, f'c =		19.3 MPa	(f'c assumed = 30.0 MPa)

CRACK CONTROL
(+ve = compression, -ve = tension)

CRACK CONTROL STEEL AND SPACING

	Bottom of Beam	Top of Beam		
As	790	0	mm^2	Total area of steel in tension
cc	23.6	0.0	mm	Clear concrete cover to steel closest to tension face
fs	-108	0	MPa	Steel stress nearest to tension face (after decompression) for crack control
Max spacing	Not Required	0.0	mm	Maximum centre-to-centre spacing of steel closest to tension face to control cracking

CRACK WIDTH ESTIMATE

Crack width estimates are only approximations based on idealized behaviour and average crack spacing.
These estimates only represent a level of cracking and should only be used in comparison with
appropriate limits such as those given below. It would not be appropriate to compare these estimates
to measured crack widths.

	Bottom of Beam	Top of Beam		
Cracked?	Yes	No		
Cracking at	5.180	0.000	m	Location of maximum crack width from left end of beam
Ms	23.80	0.00	t.m	External service moment (DL + LL)
Pdc	1191.67	0.00	kN	Prestress force at cracked centroid
Mint	5.42	0.00	t.m	Internal moment about cracked centroid
c	151.4	0.0	mm	Concrete depth in compression
Steel type	Strand	Rebar		Type of steel in tension
Method	Suri-Dilger	Gergely-Lutz		Crack width estimate equation used *
k	2.650E-6	0.00	mm^2/N	Coefficient dependent on steel type
kb	0.67	0.00		Adjustment coefficient for prestressing steel
At	87255	0	mm^2	Area of concrete in tension below the neutral axis
dc	30.0	0.0	mm	Concrete cover to center of steel closest to tension face
fs	-108	0	MPa	Stress in steel nearest to tension face (after decompression) for crack width
Est Crack Width	0.09	0.000	mm	Estimated maximum crack width
fc	10.12	0.00	MPa	Maximum concrete compressive stress - opposite face to cracking
limit	16.80	24.00	MPa	Allowable concrete compressive stress for prestressed concrete

Recommended Crack Width (mm) - Maximum Limits (from PCI Design Handbook, 5th edition)

	Critical Appearance	Prestressed Concrete	Reinforced Concrete
Exterior Exposure	0.18	0.25	0.33
Interior Exposure	0.25	0.30	0.41

* Gergely & Lutz equation: w = k1 x fs x h2 / h1 x CubicRoot(dc * A)

DEFLECTION ESTIMATE AT ALL STAGES

Design Code Used: ACI 318-11 (customized)

A. Deflections at All Stages
(-ve = deflection down, +ve = camber up)

	Net Deflection					Change in Deflection			
Location x m Column	Net @ Transfer mm A	Net @ Erection mm B	Net @ Completion mm C	Net DL @ Final mm D	Net Total @ Final mm E	DL growth + LL mm E - C	LL alone mm E - D	Span/Deflection DL growth + LL L / (E-C)	Span/Deflection LL alone L / (E-D)
0.000	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0	0
0.622	3.9	9.8	5.6	-4.7	-4.7	-10.3	0.0	1009	0
1.658	9.0	23.3	12.1	-14.3	-14.3	-26.4	0.0	392	0
2.694	12.4	33.0	15.7	-24.1	-24.1	-39.9	0.0	259	0
3.730	14.4	39.2	17.5	-31.9	-31.9	-49.4	0.0	209	0
4.766	15.3	42.1	18.2	-36.1	-36.1	-54.3	0.0	190	0
5.180	15.4	42.4	18.2	-36.5	-36.5	-54.8	0.0	189	0
5.594	15.3	42.1	18.2	-36.1	-36.1	-54.3	0.0	190	0
5.802	15.2	41.8	18.1	-35.6	-35.6	-53.7	0.0	192	0
6.630	14.4	39.2	17.5	-31.9	-31.9	-49.4	0.0	209	0
7.666	12.4	33.0	15.7	-24.1	-24.1	-39.9	0.0	259	0
8.702	9.0	23.3	12.1	-14.3	-14.3	-26.4	0.0	392	0
9.738	3.9	9.8	5.6	-4.7	-4.7	-10.3	0.0	1009	0
10.360	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0	0

Col. A: Net deflection at transfer includes prestressing and beam weight on temporary supports.
Col. B: Net deflection at erection includes prestressing and all dead loads applied before the cast-in-place
 pour plus long-time deflection growth of the prestressing and beam weight up to erection
Col. C: Net deflection at completion of construction includes prestressing and all dead loads
  plus long-time deflection growth of the prestressing and dead load up to completion
Col. D: Net DL deflection at final includes prestressing, all dead loads, and sustained live loads,
 plus long-time deflection growth.
Col. E: Net total deflection at final includes prestressing, all dead loads, and all live loads,
 plus long-time deflection growth.

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Problem: HCS 265 composite section

Deflection/camber is measured from the cast shape of the beam before release of prestressing.

Deflection growth is estimated by use of the PCI suggested multipliers - see the Deflection Multipliers report.

Span/Deflection Limits: DL growth + LL = L / 480 for non-structural attachments
L / 240 otherwise
LL alone = L / 360 for floors
L / 180 for roofs

SUPPORT ROTATION AND CHANGE OF LENGTH ESTIMATE AT ALL STAGES

Design Code Used: ACI 318-11 (customized)

B. Unrestrained Support Rotations at All Stages
(+ve = clockwise rotation)

Support Location	Net Rotation					Change in Rotation	
	Net @ Transfer	Net @ Erection	Net @ Completion	Net DL @ Final	Net Total @ Final	DL growth + LL	LL alone
Column	degrees A	degrees B	degrees C	degrees D	degrees E	degrees E - C	degrees E - D
Left	-0.3757	-0.9356	-0.5426	0.4090	0.4090	0.9516	0.0000
Right	0.3757	0.9356	0.5426	-0.4090	-0.4090	-0.9516	0.0000

C. Unrestrained Longitudinal Change of Length Due to Creep and Shrinkage
(-ve = shortening, +ve = elongation)

Elastic Shortening = -2.00 mm

	Total Change of Length (after elastic shortening)			Difference in Change		
	Erection mm B	Completion mm C	Final mm D	to Compl. mm C - B	to Final mm D - C	to Final mm D - B
Creep	-1.48	-2.15	-3.48	-0.66	-1.33	-2.00
Shrink.	-2.62	-4.08	-5.46	-1.46	-1.39	-2.84
Total	-4.10	-6.22	-8.94	-2.12	-2.72	-4.84

FLEXURAL DESIGN CHECK

Design Code Used: ACI 318-11 (customized)
Concrete compressive stress-strain model used: PCA Parabola-Rectangle Curve

Modulus of Rupture of Precast Concrete, fr = 3.94 MPa (tension)

x m	Design Moment Mu t.m	Cracking Moment Mcr t.m	Minimum Required Strength t.m	Design Strength ØMn t.m	Depth in Compression c mm	Net Tensile Strain	Flexural Classication	Ø	Warnings & Notes
0.000	0.00	5.96	0.00	0.02	0.6	1.5883	Tension	0.75	
0.622	6.44	23.55	28.26	16.27	31.5	0.0260	Tension	0.76	B
1.658	15.33	23.46	28.15	28.53	51.0	0.0149	Tension	0.85	
2.694	21.95	23.39	28.07	37.01	63.5	0.0114	Tension	0.90	
3.730	26.29	23.34	28.01	37.02	63.5	0.0114	Tension	0.90	
4.766	28.34	23.32	27.99	37.02	63.5	0.0114	Tension	0.90	
5.180	28.52	23.32	27.99	37.02	63.5	0.0114	Tension	0.90	
5.594	28.34	23.32	27.99	37.02	63.5	0.0114	Tension	0.90	
5.802	28.11	23.33	27.99	37.02	63.5	0.0114	Tension	0.90	
6.630	26.29	23.34	28.01	37.02	63.5	0.0114	Tension	0.90	
7.666	21.95	23.39	28.07	37.01	63.5	0.0114	Tension	0.90	
8.702	15.33	23.46	28.15	28.53	51.0	0.0149	Tension	0.85	
9.738	6.44	23.55	28.26	16.27	31.5	0.0260	Tension	0.76	B
10.360	0.00	5.96	0.00	0.02	0.6	1.5883	Tension	0.75	
Points of Maximum and Minimum Factored Moment									
5.180	28.52	23.32	27.99	37.02	63.5	0.0114	Tension	0.90	
0.000	0.00	4.21	0.00	0.00	0.4	0.2370	Tension	0.75	
Points of Maximum Ratio of Factored Moment to Design Strength									
5.180	28.52	23.32	27.99	37.02	63.5	0.0114	Tension	0.90	
0.000	0.00	4.21	0.00	0.00	0.4	0.2370	Tension	0.75	
Points of Maximum Ratio of Minimum Strength to Design Strength									
0.207	2.24	13.58	16.30	6.95	13.5	0.0649	Tension	0.75	B
0.000	0.00	4.21	0.00	0.00	0.4	0.2370	Tension	0.75	

Warnings & Notes
B - WARNING, ØMn<1.2Mcr and ØMn<2.0Mu or ØVn<2.0Vu, minimum reinforcement requirement not met [ACI 318-11::18.8.2].
Extent: x = 0.207 to 1.450 m, 8.910 to 10.153 m

SHEAR DESIGN CHECK

Design Code Used: ACI 318-11 (customized)

x m	Design Shear Vu kN	Prestress Component Vp kN	Concrete Strength ØVc kN	Core Fill Strength ØVc (core) kN	Required Stirrups ØVs kN	Strength Provided Stirrups ØVs kN	Total ØVn kN	Warnings & Notes
0.000	103.68	0.00	95.29	0.00	8.39	0.00	95.29	B 1 3
0.622	95.04	0.00	138.11	0.00	0.00	0.00	138.11	
1.658	73.44	0.00	95.78	0.00	0.00	0.00	95.78	
2.694	51.84	0.00	55.44	0.00	0.00	0.00	55.44	
3.730	30.24	0.00	46.27	0.00	0.00	0.00	46.27	
4.766	8.64	0.00	46.27	0.00	0.00	0.00	46.27	
5.180	0.00	0.00	46.27	0.00	0.00	0.00	46.27	
5.180	0.00	0.00	-46.27	0.00	0.00	0.00	-46.27	
5.594	-8.64	0.00	-46.27	0.00	0.00	0.00	-46.27	
5.802	-12.96	0.00	-46.27	0.00	0.00	0.00	-46.27	
6.630	-30.24	0.00	-46.27	0.00	0.00	0.00	-46.27	
7.666	-51.84	0.00	-55.44	0.00	0.00	0.00	-55.44	
8.702	-73.44	0.00	-95.78	0.00	0.00	0.00	-95.78	
9.738	-95.04	0.00	-138.11	0.00	0.00	0.00	-138.11	

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10.360	-103.68	0.00	-95.29	0.00	-8.39	0.00	-95.29	B	1	3

Warnings & Notes
B - WARNING, the factored design shear, Vu, is greater than the shear strength, ØVn, provided [ACI 318-11::11.1.1].
Extent: x = 0.000 to 0.053 m, 10.307 to 10.360 m
1 - Note, transverse shear or torsion steel is required. See the Shear/Torsion Transvese Reinforcing Design Check report.
3 - Note, design shear force at critical section near support used [ACI 318-11::11.1.3].

SHEAR TRANSVERSE REINFORCING DESIGN CHECK

Design Code Used: ACI 318-11 (customized)

x m	Shear Steel Grade fy MPa	Shear Steel Required Av/s mm^2/m	Shear Steel Provided Av/s mm^2/m	Stirrup Provided Av mm^2	Stirrup Spacing Provided s mm	Stirrup Spacing Max. Allow s mm	Warnings & Notes
0.000	400	92	0	400.00	0.0	251.3	4 5
0.622	400	0	0	400.00	0.0	251.3	
1.658	400	0	0	400.00	0.0	251.3	
2.694	400	0	0	400.00	0.0	251.3	
3.730	400	0	0	400.00	0.0	251.3	
4.766	400	0	0	400.00	0.0	251.3	
5.180	400	0	0	400.00	0.0	251.3	
5.180	400	0	0	400.00	0.0	251.3	
5.594	400	0	0	400.00	0.0	251.3	
5.802	400	0	0	400.00	0.0	251.3	
6.630	400	0	0	400.00	0.0	251.3	
7.666	400	0	0	400.00	0.0	251.3	
8.702	400	0	0	400.00	0.0	251.3	
9.738	400	0	0	400.00	0.0	251.3	
10.360	400	92	0	400.00	0.0	251.3	4 5

Warnings & Notes
4 - Note, design shear force at critical section near support used [ACI 318-11::11.1.3].
5 - Note, required stirrup spacing represents maximum code requirements [ACI 318-11::11.4.5].
Note, shear steel requirements for pre-tension bursting have NOT been included (calculation option S8).
Note, additional long. steel in compression side of section has been reduced [ACI 318-11::11.5.3.9].
* Portion of the total stirrup area required to resist torsional shear flow (one leg around periphery).
** The allowable reduction in Al within the flexural compression zone.

HORIZONTAL SHEAR DESIGN CHECK BY SECTION

Design Code Used: ACI 318-11 (customized)

Top of precast beam is considered intentionally roughened.

x m	Horizontal Shear Vu kN	Strength with no ties kN	Maximum Limit ØVnh Max kN	Required Ties Av/s mm^2/m	Tie Size Provided Av mm^2	Spacing Required s mm	Spacing Provided s mm	Strength Required ØVnh kN	Strength Provided ØVnh kN	Warnings & Notes
0.000	103.68	143.84	898.99	0	0.0	0.0	0.0	103.68	143.84	1
0.622	95.04	143.84	898.99	0	0.0	0.0	0.0	95.04	143.84	1
1.658	73.44	143.84	898.99	0	0.0	0.0	0.0	73.44	143.84	1
2.694	51.84	143.84	898.99	0	0.0	0.0	0.0	51.84	143.84	1
3.730	30.24	143.84	898.99	0	0.0	0.0	0.0	30.24	143.84	1
4.766	8.64	143.84	898.99	0	0.0	0.0	0.0	8.64	143.84	1
5.180	0.00	143.84	898.99	0	0.0	0.0	0.0	0.00	143.84	1
5.594	-8.64	-143.84	-898.99	0	0.0	0.0	0.0	-8.64	-143.84	1
5.802	-12.96	-143.84	-898.99	0	0.0	0.0	0.0	-12.96	-143.84	1
6.630	-30.24	-143.84	-898.99	0	0.0	0.0	0.0	-30.24	-143.84	1
7.666	-51.84	-143.84	-898.99	0	0.0	0.0	0.0	-51.84	-143.84	1
8.702	-73.44	-143.84	-898.99	0	0.0	0.0	0.0	-73.44	-143.84	1
9.738	-95.04	-143.84	-898.99	0	0.0	0.0	0.0	-95.04	-143.84	1
10.360	-103.68	-143.84	-898.99	0	0.0	0.0	0.0	-103.68	-143.84	1

Warnings & Notes
1 - Note, no ties required [ACI 318-11::17.5.3.3].

HORIZONTAL SHEAR DESIGN CHECK BY MOMENT REGION

Design Code Used: ACI 318-11 (customized)

Top of precast beam is considered intentionally roughened.

Region of Beam x m	Shear Length lv m	Peak Moment M t.m	Horizontal Shear Fh kN	Strength with no ties kN	Maximum Limit ØVnh Max kN	Tie Area * Required Acs mm^2	Tie Area Provided Acs mm^2	Maximum Spacing s mm	Warnings & Notes
0.000 to 5.180	5.180	28.52	1452.27	2442.90	24578.11	0.0	0.0	280.0	
5.180 to 10.360	5.180	28.52	1452.27	2442.90	24578.11	0.0	0.0	280.0	

* Required ties should be distributed in proportion to distribution of shear force (or stirrups).

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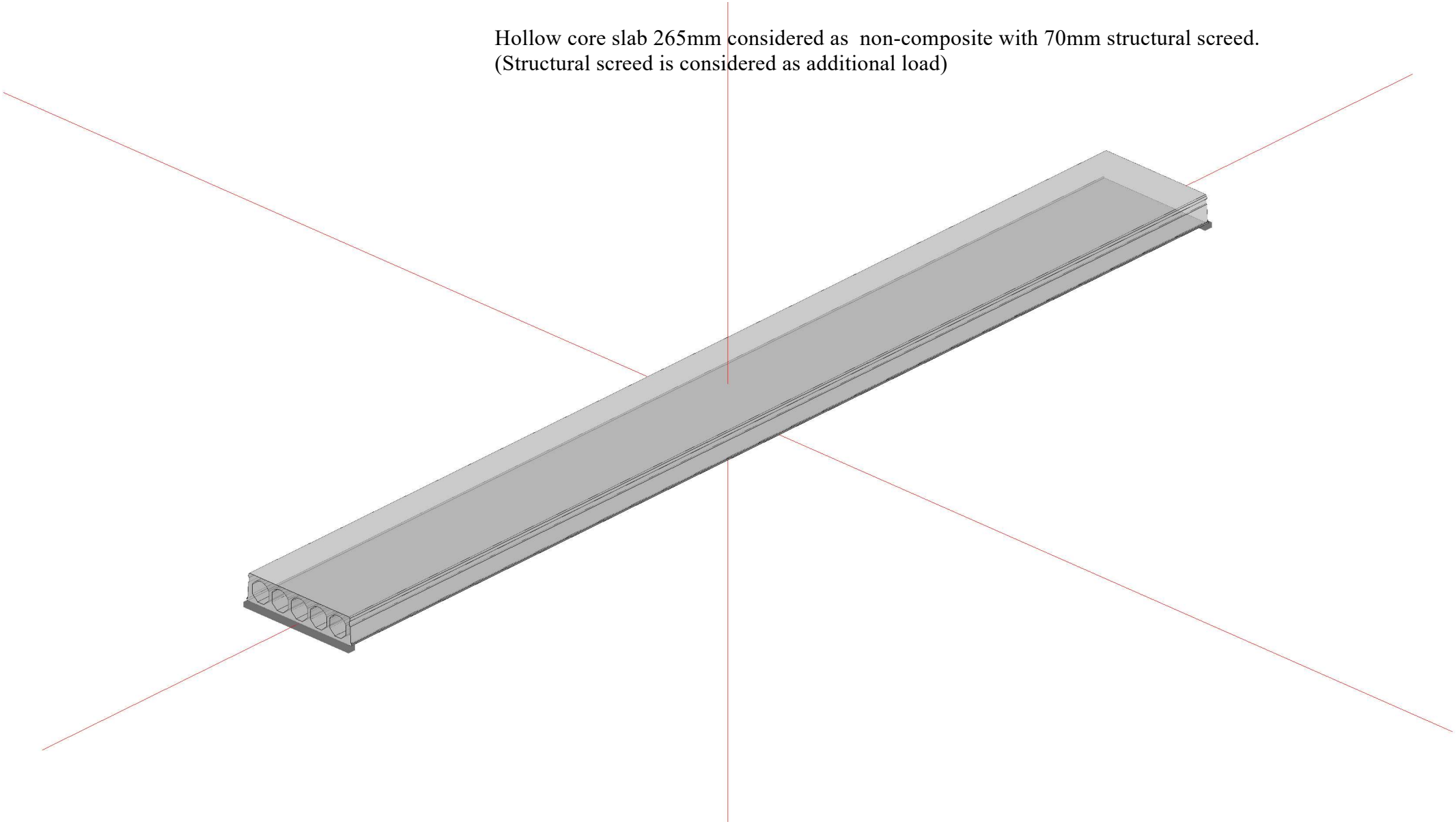
Hollow core slab 265mm considered as non-composite with 70mm structural screed.
(Structural screed is considered as additional load)



Project: BUID Dissertation - Composite action of Hollow Core slab
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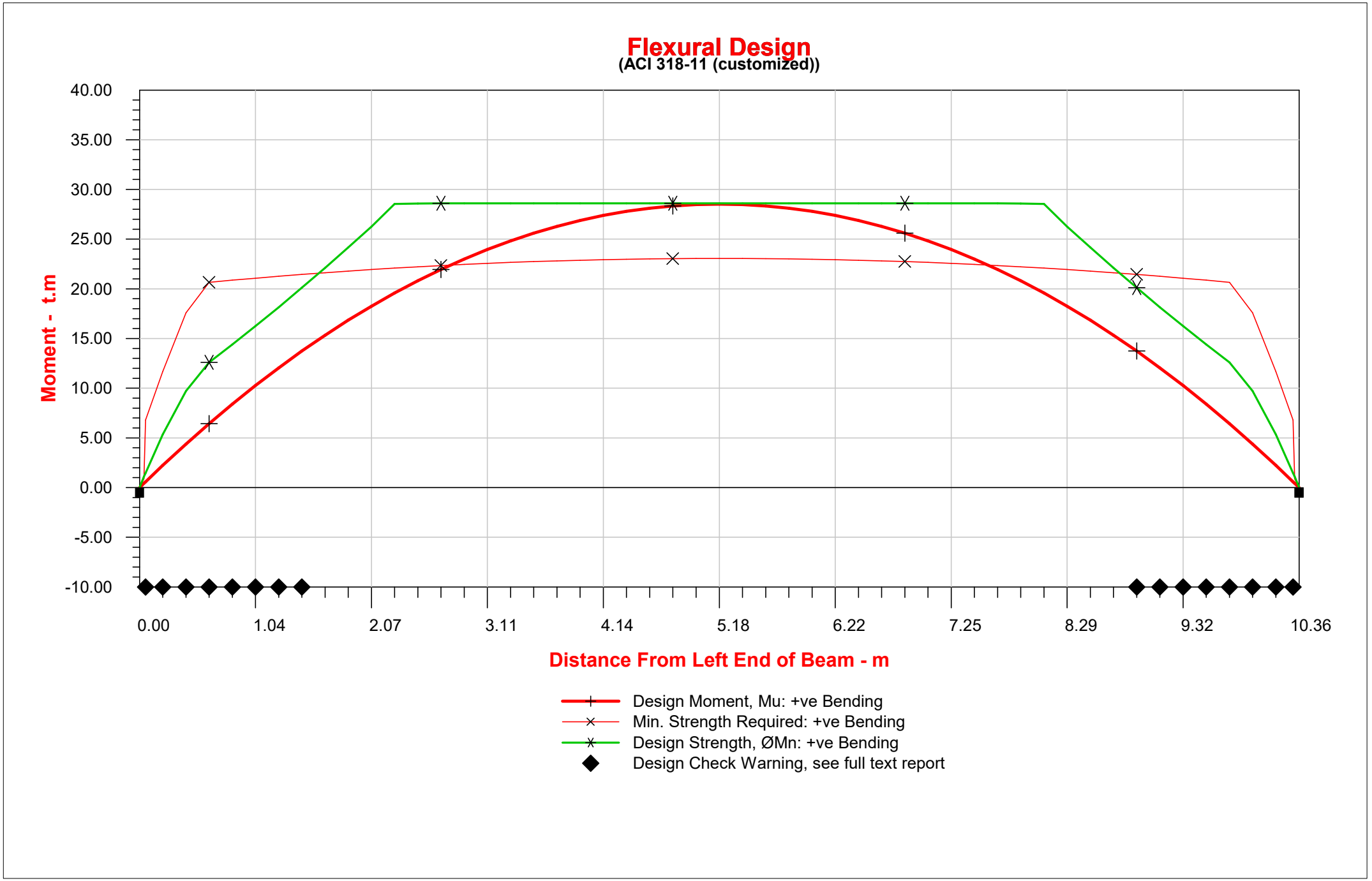

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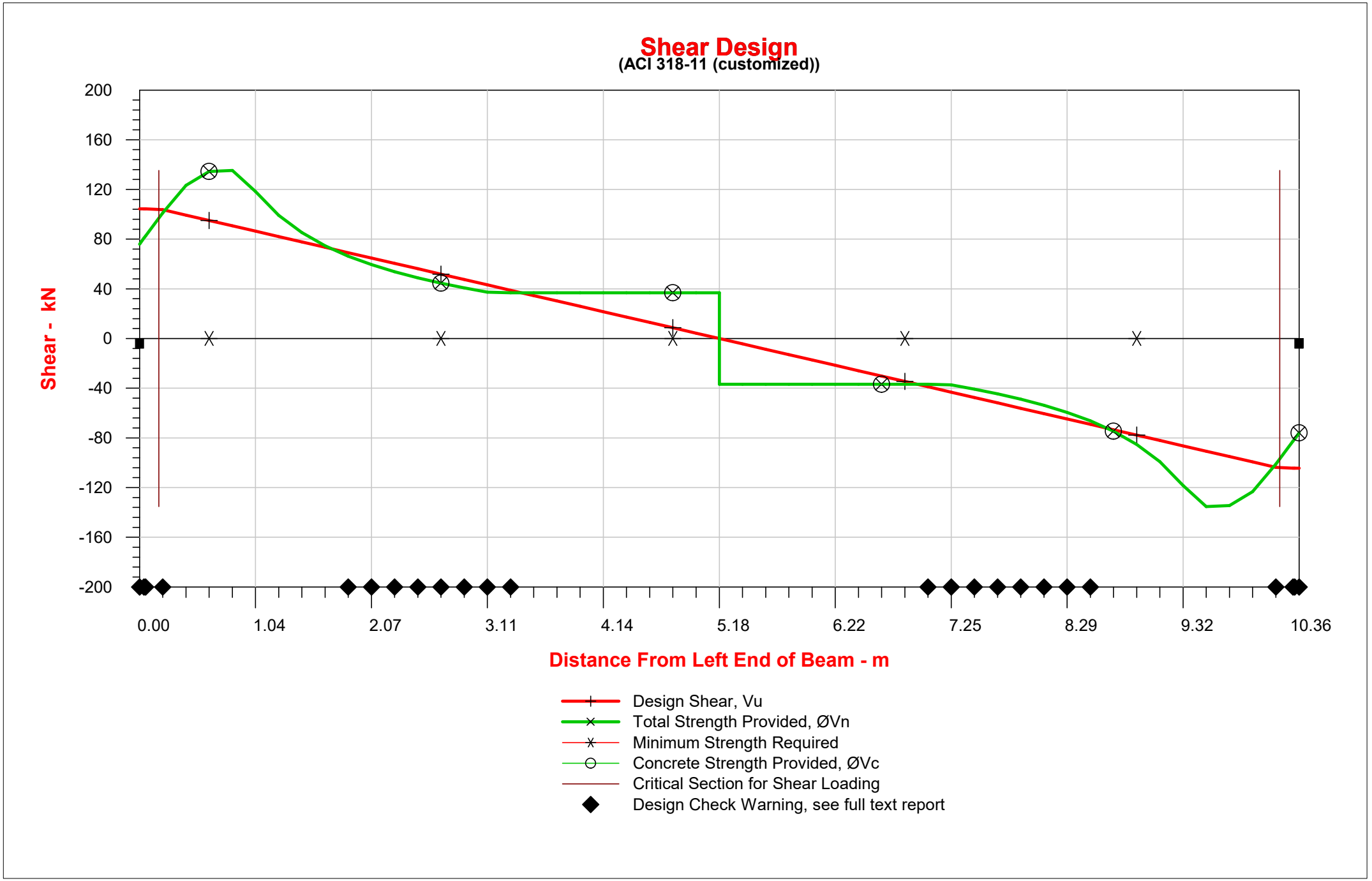

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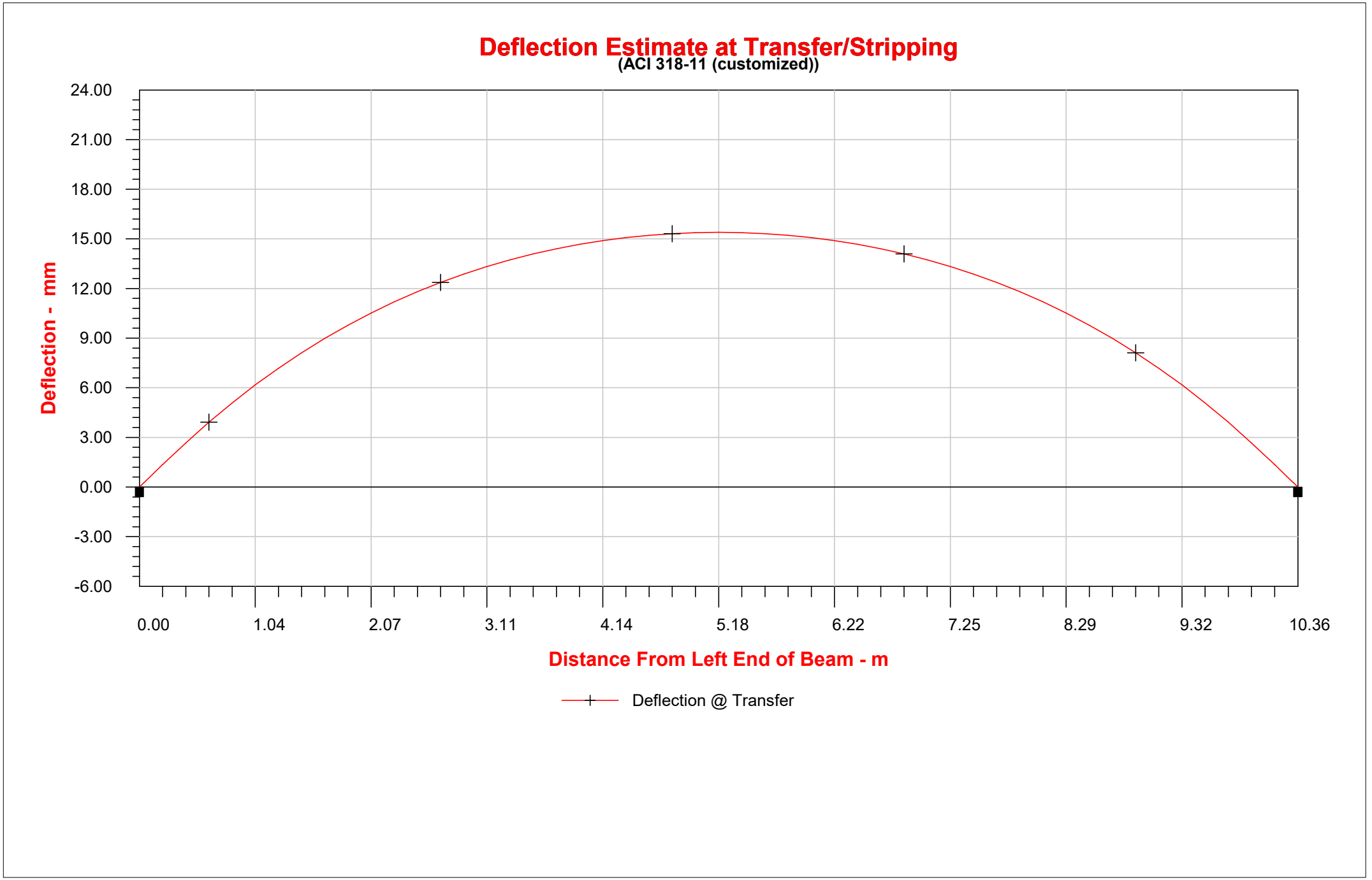
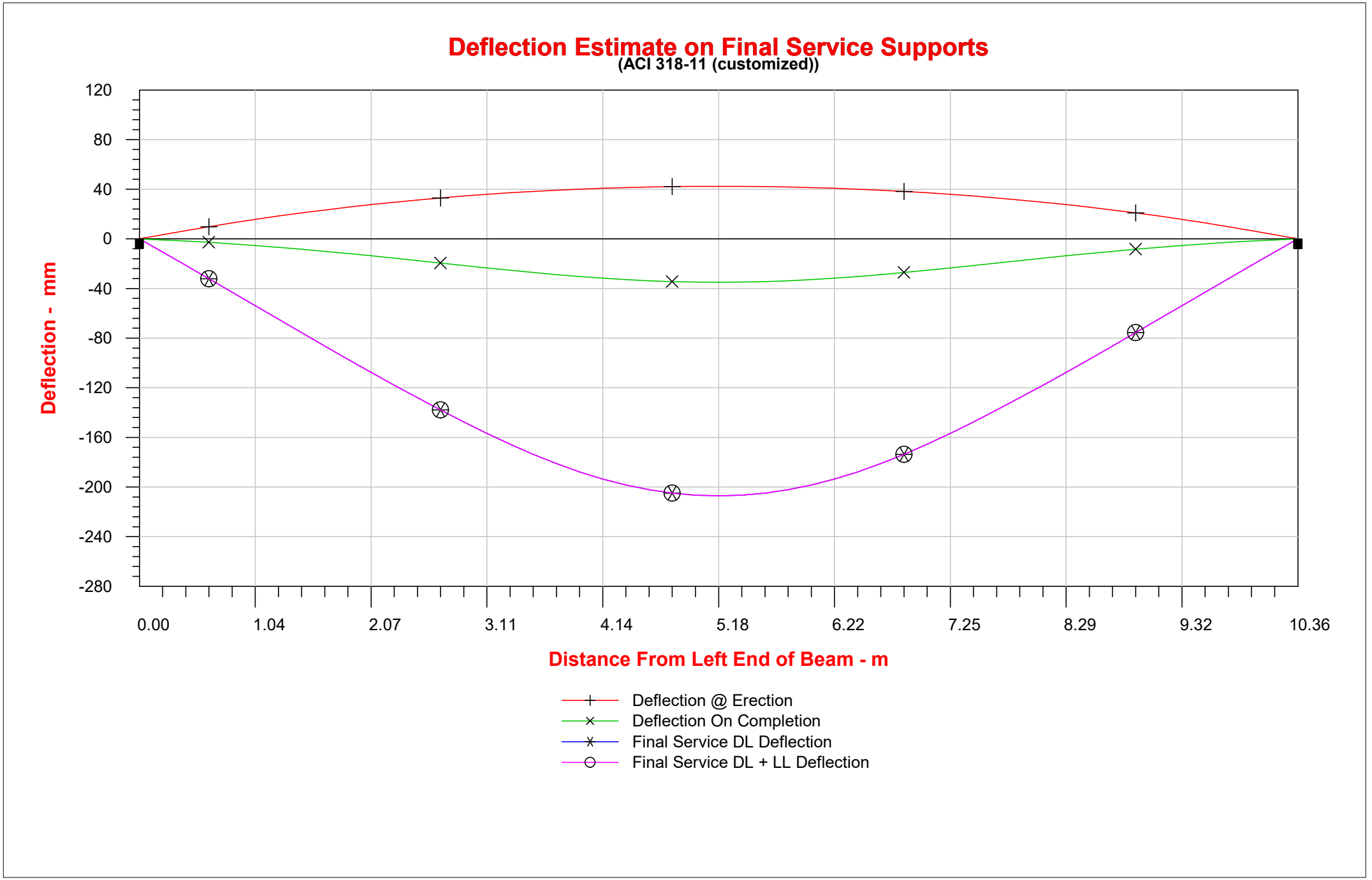
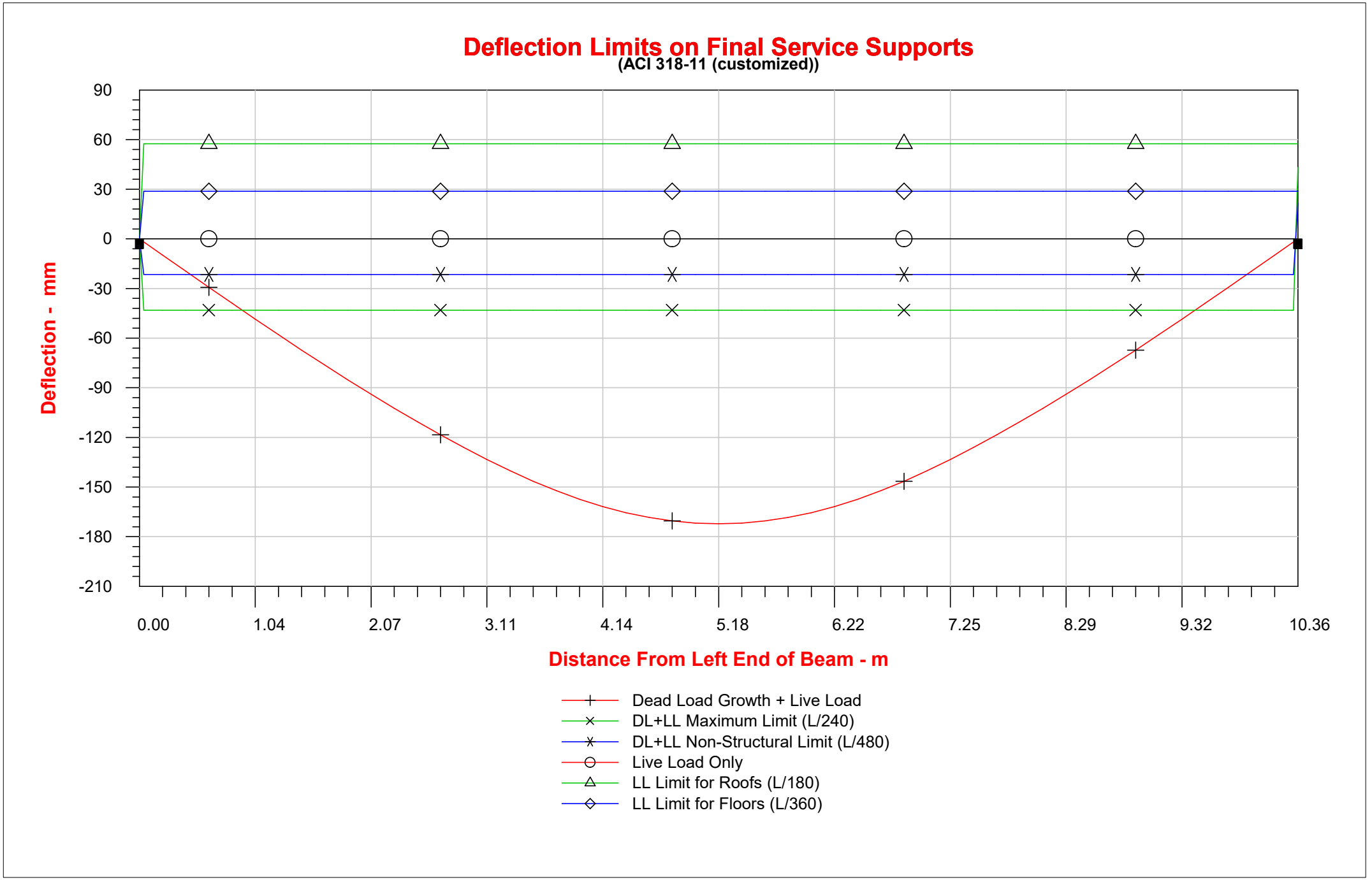


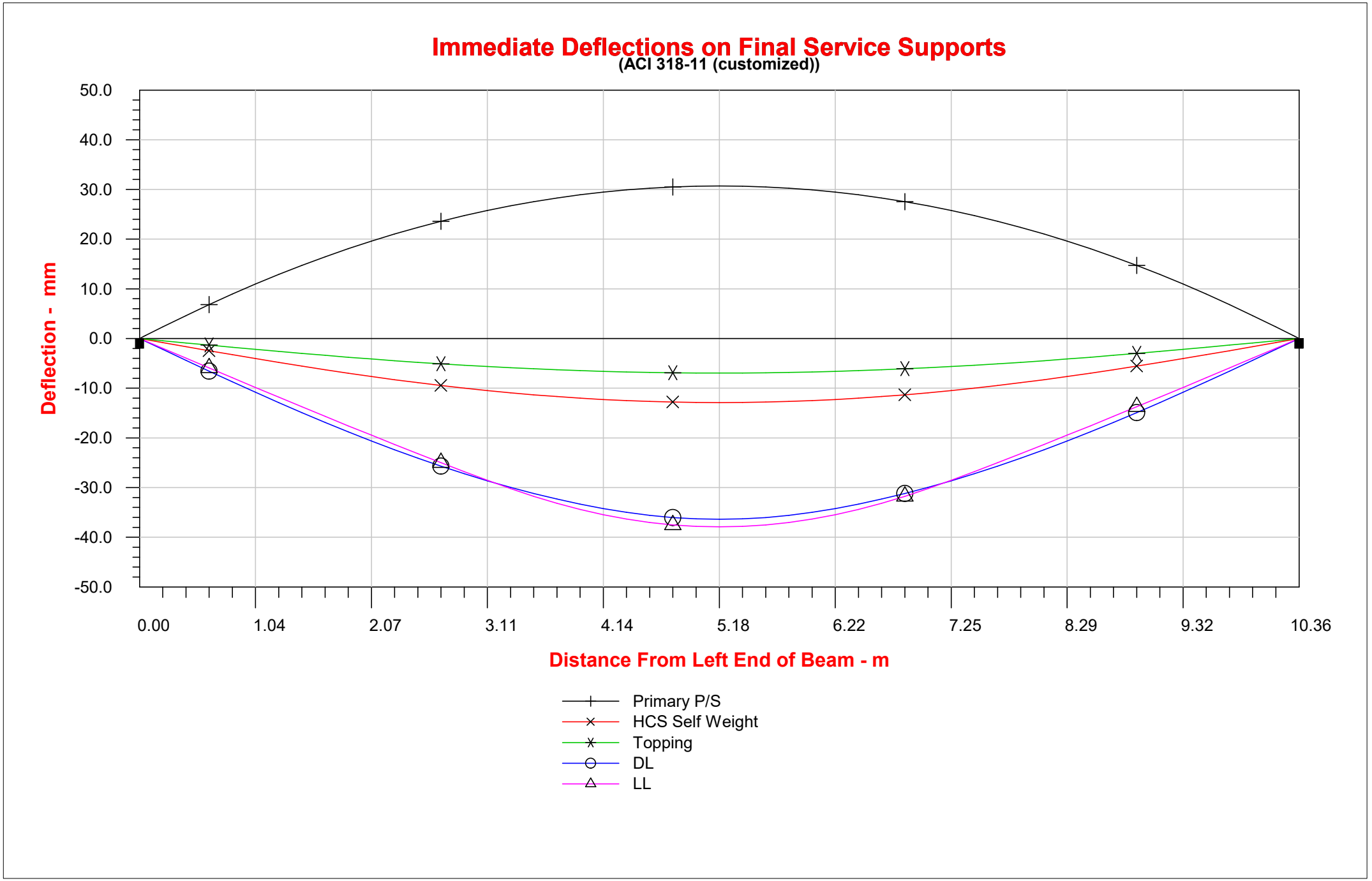
Project: BUID Dissertation - Composite action of Hollow Core slab
Problem: HCS 265 non-composite section



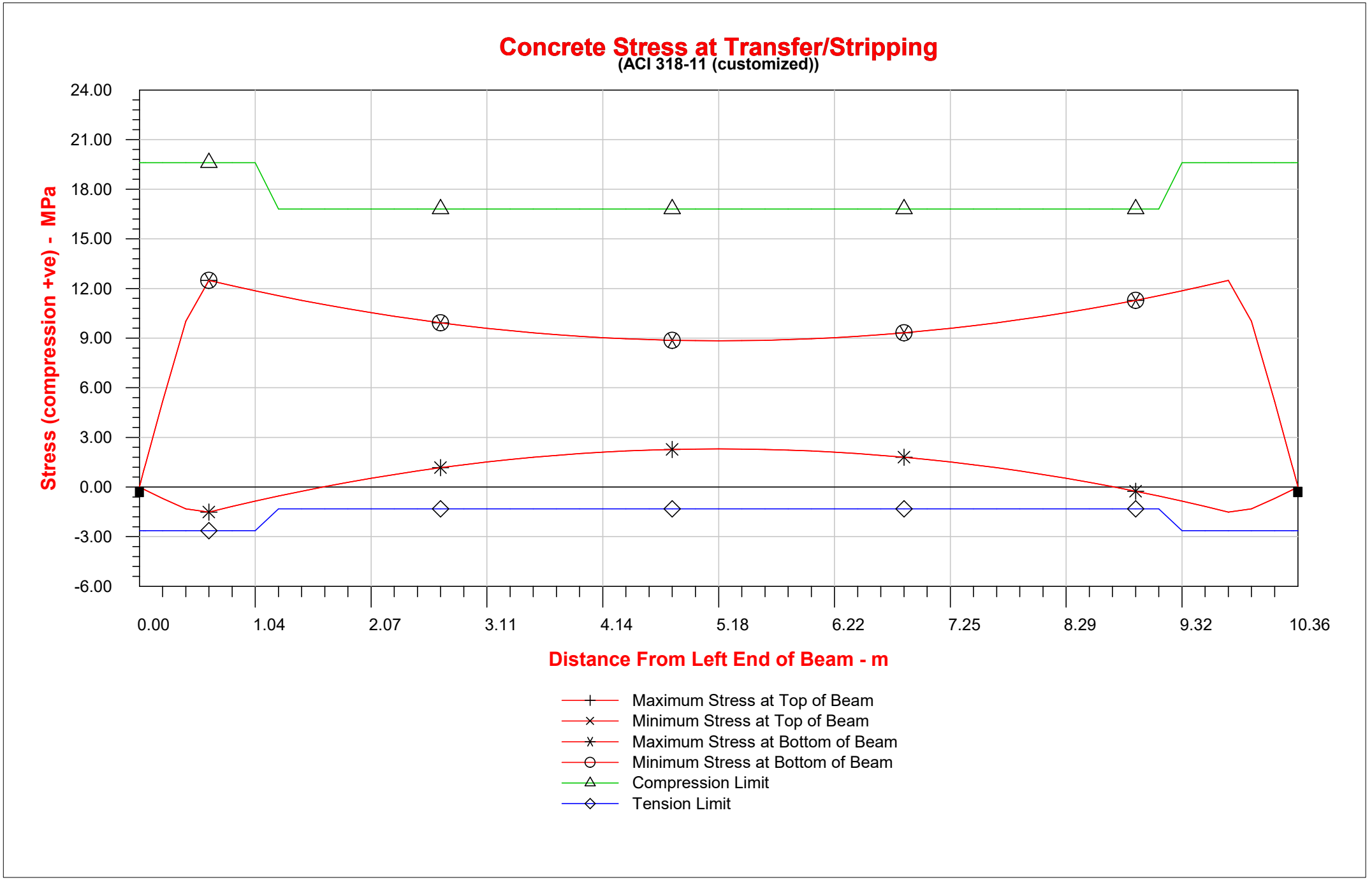
Project: BUID Dissertation - Composite action of Hollow Core slab
Problem: HCS 265 non-composite section



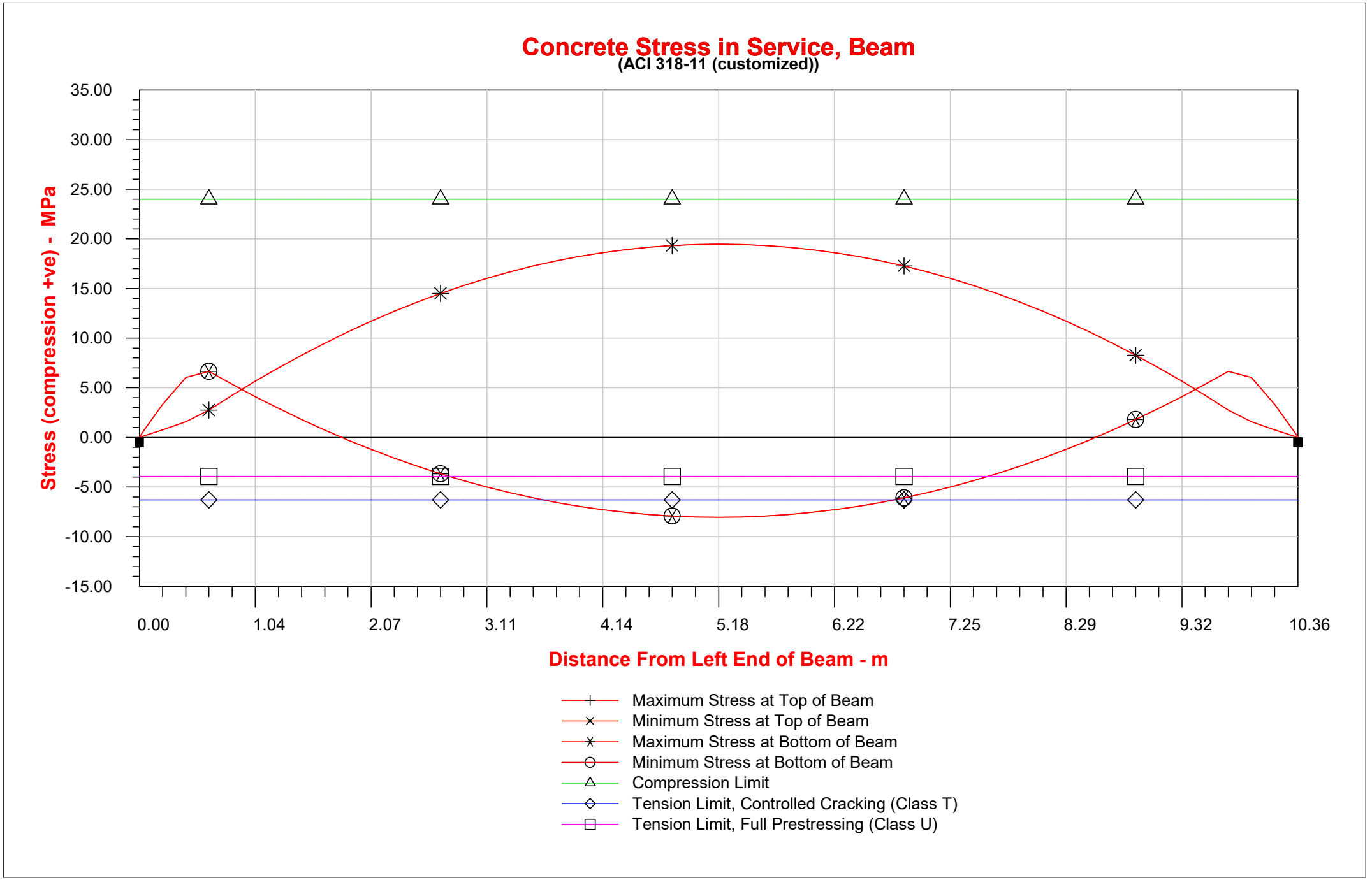
Project: BUID Dissertation - Composite action of Hollow Core slab
Problem: HCS 265 non-composite section



Project: BUID Dissertation - Composite action of Hollow Core slab
Problem: HCS 265 non-composite section



Project: BUID Dissertation - Composite action of Hollow Core slab
Problem: HCS 265 non-composite section



Project: BUID Dissertation - Composite action of Hollow Core slab
Problem: HCS 265 non-composite section

SUMMARY REPORT

Design Code Used: ACI 318-11 (customized)

NON-DEFAULT OPTION SETTINGS

** OFF ** G2: Use PCI Standard Design Practice, TR-7-05 (ACI codes only)
** ON ** P1: Vary user defined losses along beam
** OFF ** F7: Reduce ϕ in the development length of strands (CSA A23.3 only)
** OFF ** F8: Use a rectangular stress block at concrete ultimate strain
** ON ** S10: Use the ultimate section capacity for horizontal shear (moment region check)
** OFF ** D3: Have Concise Beam calculate the long-term deflection multipliers for prestressed Beams

---

CONCRETE MATERIAL PROPERTIES

		Precast Beam	
Concrete Density	Wt =	2400	kg/m^3
Compressive Strength	f'c =	40.0	MPa
Modulus of Elasticity	Ec =	31783	MPa
Strength at Transfer	f'c =	28.0	MPa
Modulus of Elast. at Transfer	Ec =	26591	MPa
Strength at Lifting	f'c =	30.0	MPa
Modulus of Elast. at Lifting	Ec =	26621	MPa

Cement Content = 410 kg/m^3
Air Content = 5.00 %
Slump = 50.0 mm
Aggregate Mix = 0.40 (fine to total aggregate ratio)
Aggregate Size = 20.0 mm
Basic Shrinkage Strain = 780.000E-6

Construction Schedule
Age at Transfer = 0.75 days
Age at Erection = 40 days
Age at Cast-in-Place Pour = 50 days
Age Cast-in-Place is Composite = 53 days
Age Construction is Complete = 143 days

Curing Method = Moist
Relative Humidity in Service = 70 %
Ambient Temperature in Service = 20 deg C

PRECAST BEAM LAYOUT

No	Segment/Length From m	To m	Length m	Section Identification Folder Name	Section Name	Section Type	Offset Z mm	Y mm
1	0.000	10.360	10.360	Standard HC	HCS265	Hollowcore	0.0	0.0

* Long offset from left end of beam. Transverse offset from top of precast to top of opening
for horizontal orientation or from center of precast to center of opening for vertical orientation.

Span Length at Transfer = 10.360 m, Centre of Supports, Left @ 0.000 m, Right @ 10.360 m
Span Length during Lift = 10.360 m, Centre of Supports, Left @ 0.000 m, Right @ 10.360 m Loop Height = 0.0 mm
Span Length in Service = 10.360 m, Centre of Supports, Left @ 0.000 m, Right @ 10.360 m
Total Beam Length = 10.360 m, Bearing Length, Left = 80.0 mm, Right = 80.0 mm

First flexural frequency of beam is approximately 2.74 Hz

GROSS PRECAST SECTION PROPERTIES (NON-COMPOSITE)
(based on Ec of the precast beam - transformed area of rebar and strand NOT included)

Seg. No.	Section Properties A mm^2	I mm^4	yb mm	Section Height mm	Section Width mm	Shear Width mm	Volume / Surface mm	Section Moduli Sb mm^3	St mm^3
1	151029	1.384E+9	133.0	265.0	1200.0	234.0	52.00	-10.405E+6	10.484E+6

UNCRACKED SECTION PROPERTIES SUMMARY

x m	Net Precast Section at Transfer (based on Eci) (include rebar,deduct strand) A mm^2	I mm^4	yb mm	Transformed Precast Section at Transfer (based on Eci) (include rebar and strand) A mm^2	I mm^4	yb mm	Transformed Precast Section in Service (based on Ec) (include rebar and strand) A mm^2	I mm^4	yb mm
0.000	150239	1.375E+9	133.5	151034	1.384E+9	133.0	151033	1.384E+9	133.0
0.622	150239	1.375E+9	133.5	156178	1.437E+9	129.6	155208	1.427E+9	130.2
1.658	150239	1.375E+9	133.5	156178	1.437E+9	129.6	155208	1.427E+9	130.2
2.694	150239	1.375E+9	133.5	156178	1.437E+9	129.6	155208	1.427E+9	130.2
3.730	150239	1.375E+9	133.5	156178	1.437E+9	129.6	155208	1.427E+9	130.2
4.766	150239	1.375E+9	133.5	156178	1.437E+9	129.6	155208	1.427E+9	130.2
5.180	150239	1.375E+9	133.5	156178	1.437E+9	129.6	155208	1.427E+9	130.2
5.594	150239	1.375E+9	133.5	156178	1.437E+9	129.6	155208	1.427E+9	130.2
5.802	150239	1.375E+9	133.5	156178	1.437E+9	129.6	155208	1.427E+9	130.2
6.630	150239	1.375E+9	133.5	156178	1.437E+9	129.6	155208	1.427E+9	130.2
7.666	150239	1.375E+9	133.5	156178	1.437E+9	129.6	155208	1.427E+9	130.2
8.702	150239	1.375E+9	133.5	156178	1.437E+9	129.6	155208	1.427E+9	130.2
9.738	150239	1.375E+9	133.5	156178	1.437E+9	129.6	155208	1.427E+9	130.2
10.360	150239	1.375E+9	133.5	151034	1.384E+9	133.0	151033	1.384E+9	133.0

These section properties can used to calculate uncracked concrete stresses using the following guidelines.

Net Precast Section at Transfer properties are used with the initial prestress after transfer (after elastic shortening loss).
Transformed Precast Section at Transfer properties are used with the precast beam self-weight.
Transformed Precast Section in Service properties are used with external loads applied to the non-composite precast beam.

PRESTRESSING STEEL TENDONS

ID	Qty	Grade MPa	Type *	Strand Size	Offsets x m	y mm	End Offset & Type Left ** m	Right ** m	Tendon Area mm2	Jacking Force Pj kN	%fpu

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1	8.000	1860	LRS	13 (1/2")	0.000 10.360	30.0 30.0	0.000 B	0.000 B	789.60	881.19	0.60	

note: * Type = LRS - Low-Relaxation Strand, SRS - Stress-Relieved Strand, PB - Plain Bar,
DB - Deformed Bar, SW - Single Wire
** End Types = B - Fully Bonded (B), D - Debonded (D), C - Cut (C), F - Full Develop (F) (fully developed)

Calculated Losses: Initial = 7.9%, Final = 10.0%
Maximum Total Prestress Forces: Pj(jacking) = 881.19 kN,
Pi(transfer) = 811.55 kN,
Pe(effective) = 793.48 kN @ x = 5.180 m,

See the "Development Length" text report for details of the strand transfer and development lengths

TRANSVERSE SHEAR STEEL

Shear Stirrups

From m	To m	Grade MPa	Size	# of Legs	Total Area mm^2	Spacing mm
0.000	10.360	400	15M	2	400.0	0.0

Interface Shear Ties

From m	To m	Grade MPa	Size	# of Legs	Total Area mm^2	Spacing mm
0.000	10.360	400	15M	0	0.0	0.0

APPLIED LOADS

Load Group & Type	Stages Applied & Distribution	Load Details (left to right)
HCS Self Weight D: DL, General	Transfer to Final Service No Load Distribution	HCS Self Weight- Area: 3.25 kN/m^2 full length, 1.2 m wide
Topping D: DL, General	Grouting to Final Service No Load Distribution	Topping- Area: 1.75 kN/m^2 full length, 1.2 m wide
DL D: DL, General	Completion to Final Service No Load Distribution	SDL- Area: 7.5 kN/m^2 full length, 1.2 m wide
LL L: LL, General	Completion to Final Service No Load Distribution	LL- Area: 2 kN/m^2 full length, 1.2 m wide

Some load groups are generated automatically by Concise Beam.

LOAD COMBINATIONS

Serviceability (SLS) & Fatigue (FLS) Limit State Combinations (used individually)
SLS Stress : 1.00P + 1.00D + 1.00F + 1.00T + 1.00L + 1.00L1 + 1.00Lr + 1.00R + 1.00S + 1.00Ws + 0.60Wu
SLS Deflect : 1.00P + 1.00D + 1.00F + 1.00T + 1.00L + 1.00L1 + 1.00Lr + 1.00R + 1.00S
FLS Fatigue : 1.00P + 1.00D + 1.00F + 1.00L + 1.00L1 + 1.00Lr

Ultimate (Strength) Limit State (ULS) Combinations (searched collectively to obtain envelope)
1: Case 1 : 1.15D + 1.50L + 0.40Lr
2: Case 2 : 1.15D + 0.90L + 1.50Lr
3: Case 3 : 1.30D

COMBINED ANALYSIS IN SERVICE (external loads only)

Station	SLS (stress) Load Combination			ULS Load Envelopes							
	Moment	Moment		Shear				Moment			
x	Sustained	Total Load		Total Load		Govern. Combo.		Total Load		Govern. Combo.	
m	t.m	t.m		kN				t.m			
		min	max	min	max	min	max	min	max	min	max
0.000	0.00	0.00	0.00	100.54	108.00	2	1	0.00	0.00	1	1
0.622	5.37	5.37	5.37	88.48	95.04	2	1	5.99	6.44	2	1
1.658	12.80	12.80	12.80	68.37	73.44	2	1	14.28	15.33	2	1
2.694	18.32	18.32	18.32	48.26	51.84	2	1	20.44	21.95	2	1
3.730	21.94	21.94	21.94	28.15	30.24	2	1	24.47	26.29	2	1
4.766	23.65	23.65	23.65	8.04	8.64	2	1	26.38	28.34	2	1
5.180	23.80	23.80	23.80	0.00	0.00	1	1	26.55	28.52	2	1
5.594	23.65	23.65	23.65	-8.64	-8.04	1	2	26.38	28.34	2	1
5.802	23.46	23.46	23.46	-12.96	-12.07	1	2	26.17	28.11	2	1
6.630	21.94	21.94	21.94	-30.24	-28.15	1	2	24.47	26.29	2	1
7.666	18.32	18.32	18.32	-51.84	-48.26	1	2	20.44	21.95	2	1
8.702	12.80	12.80	12.80	-73.44	-68.37	1	2	14.28	15.33	2	1
9.738	5.37	5.37	5.37	-95.04	-88.48	1	2	5.99	6.44	2	1
10.360	0.00	0.00	0.00	-108.00	-100.54	1	2	0.00	0.00	1	1

COMBINED SUPPORT REACTIONS, ALL STAGES
(+ve = upwards, counter-clockwise)

Unfactored Load Group Effects

Load Group	Initial Lifting		Erection Lifting		During CIP Pour		In Service			
	Left	Right	Left	Right	Left	Right	Left		Right	
	Vertical kN	Vertical kN	Vertical kN	Vertical kN	Vertical kN	Vertical kN	Vertical kN	Torsion t.m	Vertical kN	Torsion t.m

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HCS Self Wei	20.20	20.20	20.20	20.20	20.20	20.20	20.20	0.00	20.20	0.00
Topping					10.88	10.88	10.88	0.00	10.88	0.00
DL							46.62	0.00	46.62	0.00
LL							12.43	0.00	12.43	0.00

Load Envelope Effects

Load Envelope	Initial Lifting Left Vertical kN	Initial Lifting Right Vertical kN	Erection Lifting Left Vertical kN	Erection Lifting Right Vertical kN	During CIP Pour Left Vertical kN	During CIP Pour Right Vertical kN	In Service Left Vertical[*] kN	In Service Left Torsion[*] t.m	In Service Right Vertical[*] kN	In Service Right Torsion[*] t.m
SLS DL							77.70	0.00	77.70	0.00
SLS Sustain							90.13	0.00	90.13	0.00
SLS Minimum	20.20	20.20	20.20	20.20	31.08	31.08	90.13	0.00	90.13	0.00
SLS Maximum	20.20	20.20	20.20	20.20	31.08	31.08	90.13	0.00	90.13	0.00
ULS Minimum							100.54 [2]	0.00 [1]	100.54 [2]	0.00 [1]
ULS Maximum							108.00 [1]	0.00 [1]	108.00 [1]	0.00 [1]

* Governing ULS Load Combination (below)

CONCRETE STRESS RESULTS (UNCRACKED ANALYSIS)
(+ve = compression, -ve = tension)

Location	x m	Stress MPa	Limit * MPa	Overstress Notice	
STRESSES AT TRANSFER					
Critical Compression					
Top of Beam	5.180	2.30	16.80	0%	
Bottom of Beam	1.243	11.57	16.80	0%	
					Longitudinal Tensile Rebar Needed (mm^2)
Critical Tension					Required / Provided / Additional
Top of Beam	0.622	-1.52	-2.64	0%	
Bottom of Beam	0.000	0.01	-2.64	0%	
STRESSES DURING INITIAL LIFTING					
Critical Compression					
Top of Beam	5.180	2.30	18.00	0%	
Bottom of Beam	1.243	11.57	18.00	0%	
					Longitudinal Tensile Rebar Needed (mm^2)
Critical Tension					Required / Provided / Additional
Top of Beam	0.622	-1.52	-2.73	0%	
Bottom of Beam	0.000	0.01	-2.73	0%	
STRESSES DURING ERECTION LIFTING					
Critical Compression					
Top of Beam	5.180	2.34	24.00	0%	
Bottom of Beam	1.243	10.72	24.00	0%	
					Longitudinal Tensile Rebar Needed (mm^2)
Critical Tension					Required / Provided / Additional
Top of Beam	0.622	-1.31	-3.15	0%	
Bottom of Beam	0.000	0.01	-3.15	0%	
STRESSES IN SERVICE					
Critical Compression					
Top of Beam	5.180	19.48	24.00	0%	
Bottom of Beam	0.622	6.66	24.00	0%	
Critical Tension					
Top of Beam	0.000	0.00	-6.30	0%	Class U member - not cracked
Bottom of Beam	5.180	-8.05	-6.30	28%	Class C member - check cracking and cover
STRESSES IN SERVICE (SUSTAINED LOADS ONLY)					
Critical Compression					
Top of Beam	5.180	19.48	18.00	8%	
Bottom of Beam	0.622	6.66	18.00	0%	

* Tensile stress limit given is for Class T (controlled cracking). Beyond this limit crack control is required.

	At Transfer	During Lifting	In Service
Modulus of Rupture, fr =	-3.30 MPa	-3.41 MPa	-3.94 MPa

Strength Required for Transfer, f'ci = 19.3 MPa (f'c specified = 28.0 MPa)
Strength Required for Initial Lifting, f'c = 19.3 MPa (f'c assumed = 30.0 MPa)

CRACK CONTROL
(+ve = compression, -ve = tension)

CRACK CONTROL STEEL AND SPACING

	Bottom of Beam	Top of Beam		
As	790	0	mm^2	Total area of steel in tension
cc	23.6	0.0	mm	Clear concrete cover to steel closest to tension face
fs	-248	0	MPa	Steel stress nearest to tension face (after decompression) for crack control
Max spacing	225.8	0.0	mm	Maximum centre-to-centre spacing of steel closest to tension face to control cracking

CRACK WIDTH ESTIMATE

Crack width estimates are only approximations based on idealized behaviour and average crack spacing.
These estimates only represent a level of cracking and should only be used in comparison with
appropriate limits such as those given below. It would not be appropriate to compare these estimates
to measured crack widths.

	Bottom of Beam	Top of Beam

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Cracked?	Yes	No		
Cracking at	5.180	0.000	m	Location of maximum crack width from left end of beam
Ms	23.80	0.00	t.m	External service moment (DL + LL)
Pdc	863.12	0.00	kN	Prestress force at cracked centroid
Mint	7.18	0.00	t.m	Internal moment about cracked centroid
c	85.0	0.0	mm	Concrete depth in compression
Steel type	Strand	Rebar		Type of steel in tension
Method	Suri-Dilger	Gergely-Lutz		Crack width estimate equation used *
k	2.650E-6	0.00	mm^2/N	Coefficient dependent on steel type
kb	0.67	0.00		Adjustment coefficient for prestressing steel
At	86295	0	mm^2	Area of concrete in tension below the neutral axis
dc	30.0	0.0	mm	Concrete cover to center of steel closest to tension face
fs	-301	0	MPa	Stress in steel nearest to tension face (after decompression) for crack width
Est Crack Width	0.25	0.000	mm	Estimated maximum crack width
fc	27.09	0.01	MPa	Maximum concrete compressive stress - opposite face to cracking
limit	24.00	24.00	MPa	Allowable concrete compressive stress for prestressed concrete

Recommended Crack Width (mm) - Maximum Limits (from PCI Design Handbook, 5th edition)

	Critical Appearance	Prestressed Concrete	Reinforced Concrete
Exterior Exposure	0.18	0.25	0.33
Interior Exposure	0.25	0.30	0.41

* Gergely & Lutz equation: w = k1 x fs x h2 / h1 x CubicRoot(dc * A)

DEFLECTION ESTIMATE AT ALL STAGES

Design Code Used: ACI 318-11 (customized)

A. Deflections at All Stages
(-ve = deflection down, +ve = camber up)

Location x m Column	Net Deflection: Net @ Transfer mm A	Net @ Erection mm B	Net @ Completion mm C	Net DL @ Final mm D	Net Total @ Final mm E	Change in Deflection: DL growth + LL mm E - C	LL alone mm E - D	Span/Deflection: DL growth + LL L / (E-C)	LL alone L / (E-D)
0.000	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0	0
0.622	3.9	9.8	-2.8	-32.1	-32.1	-29.3	0.0	353	0
1.658	9.0	23.3	-10.1	-86.4	-86.4	-76.3	0.0	135	0
2.694	12.4	33.0	-19.4	-137.9	-137.9	-118.5	0.0	87	0
3.730	14.4	39.2	-28.8	-181.1	-181.1	-152.3	0.0	68	0
4.766	15.3	42.1	-34.4	-204.9	-204.9	-170.5	0.0	60	0
5.180	15.4	42.4	-35.0	-207.2	-207.2	-172.2	0.0	60	0
5.594	15.3	42.1	-34.4	-204.9	-204.9	-170.5	0.0	60	0
5.802	15.2	41.8	-33.8	-202.2	-202.2	-168.4	0.0	61	0
6.630	14.4	39.2	-28.8	-181.1	-181.1	-152.3	0.0	68	0
7.666	12.4	33.0	-19.4	-137.9	-137.9	-118.5	0.0	87	0
8.702	9.0	23.3	-10.1	-86.4	-86.4	-76.3	0.0	135	0
9.738	3.9	9.8	-2.8	-32.1	-32.1	-29.3	0.0	353	0
10.360	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0	0

Col. A: Net deflection at transfer includes prestressing and beam weight on temporary supports.
Col. B: Net deflection at erection includes prestressing and all dead loads applied before the cast-in-place pour plus long-time deflection growth of the prestressing and beam weight up to erection
Col. C: Net deflection at completion of construction includes prestressing and all dead loads plus long-time deflection growth of the prestressing and dead load up to completion
Col. D: Net DL deflection at final includes prestressing, all dead loads, and sustained live loads, plus long-time deflection growth.
Col. E: Net total deflection at final includes prestressing, all dead loads, and all live loads, plus long-time deflection growth.

Deflection/camber is measured from the cast shape of the beam before release of prestressing.

Deflection growth is estimated by use of the PCI suggested multipliers - see the Deflection Multipliers report.

Span/Deflection Limits: DL growth + LL = L / 480 for non-structural attachments
L / 240 otherwise
LL alone = L / 360 for floors
L / 180 for roofs

SUPPORT ROTATION AND CHANGE OF LENGTH ESTIMATE AT ALL STAGES

Design Code Used: ACI 318-11 (customized)

B. Unrestrained Support Rotations at All Stages
(+ve = clockwise rotation)

Support Location Column	Net Rotation: Net @ Transfer degrees A	Net @ Erection degrees B	Net @ Completion degrees C	Net DL @ Final degrees D	Net Total @ Final degrees E	Change in Rotation: DL growth + LL degrees E - C	LL alone degrees E - D
Left	-0.3755	-0.9352	0.2290	2.9373	2.9373	2.7083	0.0000
Right	0.3755	0.9352	-0.2290	-2.9373	-2.9373	-2.7083	0.0000

C. Unrestrained Longitudinal Change of Length Due to Creep and Shrinkage
(-ve = shortening, +ve = elongation)

Elastic Shortening = -1.99 mm

Total Change of Length (after elastic shortening): Erection mm B	Completion mm C	Final mm D	Difference in Change: to Compl. mm C - B	to Final mm D - C	to Final mm D - B

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Creep		-1.48	-2.15	-3.48		-0.66	-1.33	-2.00
Shrink.		-2.62	-4.08	-5.46		-1.46	-1.39	-2.84
Total		-4.10	-6.22	-8.94		-2.12	-2.72	-4.84

FLEXURAL DESIGN CHECK

Design Code Used: ACI 318-11 (customized)
Concrete compressive stress-strain model used: PCA Parabola-Rectangle Curve

Modulus of Rupture of Precast Concrete, fr = 3.94 MPa (tension)

x m	Design Moment Mu t.m	Cracking Moment Mcr t.m	Minimum Required Strength t.m	Design Strength ØMn t.m	Depth in Compression c mm	Net Tensile Strain	Flexural Classication	Ø	Warnings & Notes
0.000	0.00	4.19	0.00	0.02	0.5	1.4812	Tension	0.75	
0.622	6.44	17.21	20.65	12.60	24.2	0.0261	Tension	0.76	B
1.658	15.33	18.02	21.62	22.11	39.3	0.0150	Tension	0.85	
2.694	21.95	18.62	22.34	28.60	51.1	0.0108	Tension	0.90	
3.730	26.29	19.01	22.82	28.60	51.1	0.0108	Tension	0.90	
4.766	28.34	19.20	23.04	28.60	51.1	0.0108	Tension	0.90	
5.180	28.52	19.22	23.06	28.60	51.1	0.0108	Tension	0.90	
5.594	28.34	19.20	23.04	28.60	51.1	0.0108	Tension	0.90	
5.802	28.11	19.18	23.01	28.60	51.1	0.0108	Tension	0.90	
6.630	26.29	19.01	22.82	28.60	51.1	0.0108	Tension	0.90	
7.666	21.95	18.62	22.34	28.60	51.1	0.0108	Tension	0.90	
8.702	15.33	18.02	21.62	22.11	39.3	0.0150	Tension	0.85	
9.738	6.44	17.21	20.65	12.60	24.2	0.0261	Tension	0.76	B
10.360	0.00	4.19	0.00	0.02	0.5	1.4812	Tension	0.75	
Points of Maximum and Minimum Factored Moment									
5.180	28.52	19.22	23.06	28.60	51.1	0.0108	Tension	0.90	
0.000	0.00	4.21	0.00	0.00	0.4	0.2370	Tension	0.75	
Points of Maximum Ratio of Factored Moment to Design Strength									
5.180	28.52	19.22	23.06	28.60	51.1	0.0108	Tension	0.90	
0.000	0.00	4.21	0.00	0.00	0.4	0.2370	Tension	0.75	
Points of Maximum Ratio of Minimum Strength to Design Strength									
0.053	0.58	5.66	6.79	1.46	2.7	0.2606	Tension	0.75	B
0.000	0.00	4.21	0.00	0.00	0.4	0.2370	Tension	0.75	

Warnings & Notes
B - WARNING, ØMn<1.2Mcr and ØMn<2.0Mu or ØVn<2.0Vu, minimum reinforcement requirement not met [ACI 318-11::18.8.2].
Extent: x = 0.053 to 1.450 m, 8.910 to 10.307 m

SHEAR DESIGN CHECK

Design Code Used: ACI 318-11 (customized)

x m	Design Shear Vu kN	Prestress Component Vp kN	Concrete Strength ØVc kN	Core Fill Strength ØVc (core) kN	Required Stirrups ØVs kN	Strength Provided Stirrups ØVs kN	Provided Total ØVn kN	Warnings & Notes
0.000	104.41	0.00	75.88	0.00	28.53	0.00	75.88	B 1 3
0.622	95.04	0.00	134.49	0.00	0.00	0.00	134.49	
1.658	73.44	0.00	74.68	0.00	0.00	0.00	74.68	
2.694	51.84	0.00	44.50	0.00	13.80	0.00	44.50	B 1
3.730	30.24	0.00	36.82	0.00	0.00	0.00	36.82	
4.766	8.64	0.00	36.82	0.00	0.00	0.00	36.82	
5.180	0.00	0.00	36.82	0.00	0.00	0.00	36.82	
5.180	0.00	0.00	-36.82	0.00	0.00	0.00	-36.82	
5.594	-8.64	0.00	-36.82	0.00	0.00	0.00	-36.82	
5.802	-12.96	0.00	-36.82	0.00	0.00	0.00	-36.82	
6.630	-30.24	0.00	-36.82	0.00	0.00	0.00	-36.82	
7.666	-51.84	0.00	-44.50	0.00	-13.80	0.00	-44.50	B 1
8.702	-73.44	0.00	-74.68	0.00	0.00	0.00	-74.68	
9.738	-95.04	0.00	-134.49	0.00	0.00	0.00	-134.49	
10.360	-104.41	0.00	-75.88	0.00	-28.53	0.00	-75.88	B 1 3

Warnings & Notes
B - WARNING, the factored design shear, Vu, is greater than the shear strength, ØVn, provided [ACI 318-11::11.1.1].
Extent: x = 0.000 to 0.207 m, 1.865 to 3.315 m, 7.045 to 8.495 m, 10.153 to 10.360 m
1 - Note, transverse shear or torsion steel is required. See the Shear/Torsion Transvese Reinforcing Design Check report.
3 - Note, design shear force at critical section near support used [ACI 318-11::11.1.3].

SHEAR TRANSVERSE REINFORCING DESIGN CHECK

Design Code Used: ACI 318-11 (customized)

x m	Shear Steel Grade fy MPa	Shear Steel Required Av/s mm^2/m	Shear Steel Provided Av/s mm^2/m	Stirrup Provided Av mm^2	Stirrup Spacing Provided s mm	Stirrup Spacing Max. Allow s mm	Warnings & Notes
0.000	400	405	0	400.00	0.0	198.8	4 5
0.622	400	0	0	400.00	0.0	198.8	
1.658	400	0	0	400.00	0.0	198.8	
2.694	400	196	0	400.00	0.0	198.8	1 5
3.730	400	0	0	400.00	0.0	198.8	
4.766	400	0	0	400.00	0.0	198.8	
5.180	400	0	0	400.00	0.0	198.8	
5.180	400	0	0	400.00	0.0	198.8	
5.594	400	0	0	400.00	0.0	198.8	
5.802	400	0	0	400.00	0.0	198.8	
6.630	400	0	0	400.00	0.0	198.8	
7.666	400	196	0	400.00	0.0	198.8	1 5
8.702	400	0	0	400.00	0.0	198.8	
9.738	400	0	0	400.00	0.0	198.8	
10.360	400	405	0	400.00	0.0	198.8	4 5

Warnings & Notes
1 - Note, amount of shear steel required represents minimum code requirements [ACI 318-11::11.4.6.3/4].

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4 - Note, design shear force at critical section near support used [ACI 318-11::11.1.3].
5 - Note, required stirrup spacing represents maximum code requirements [ACI 318-11::11.4.5].
Note, shear steel requirements for pre-tension bursting have NOT been included (calculation option S8).
Note, additional long. steel in compression side of section has been reduced [ACI 318-11::11.5.3.9].
* Portion of the total stirrup area required to resist torsional shear flow (one leg around periphery).
** The allowable reduction in Al within the flexural compression zone.