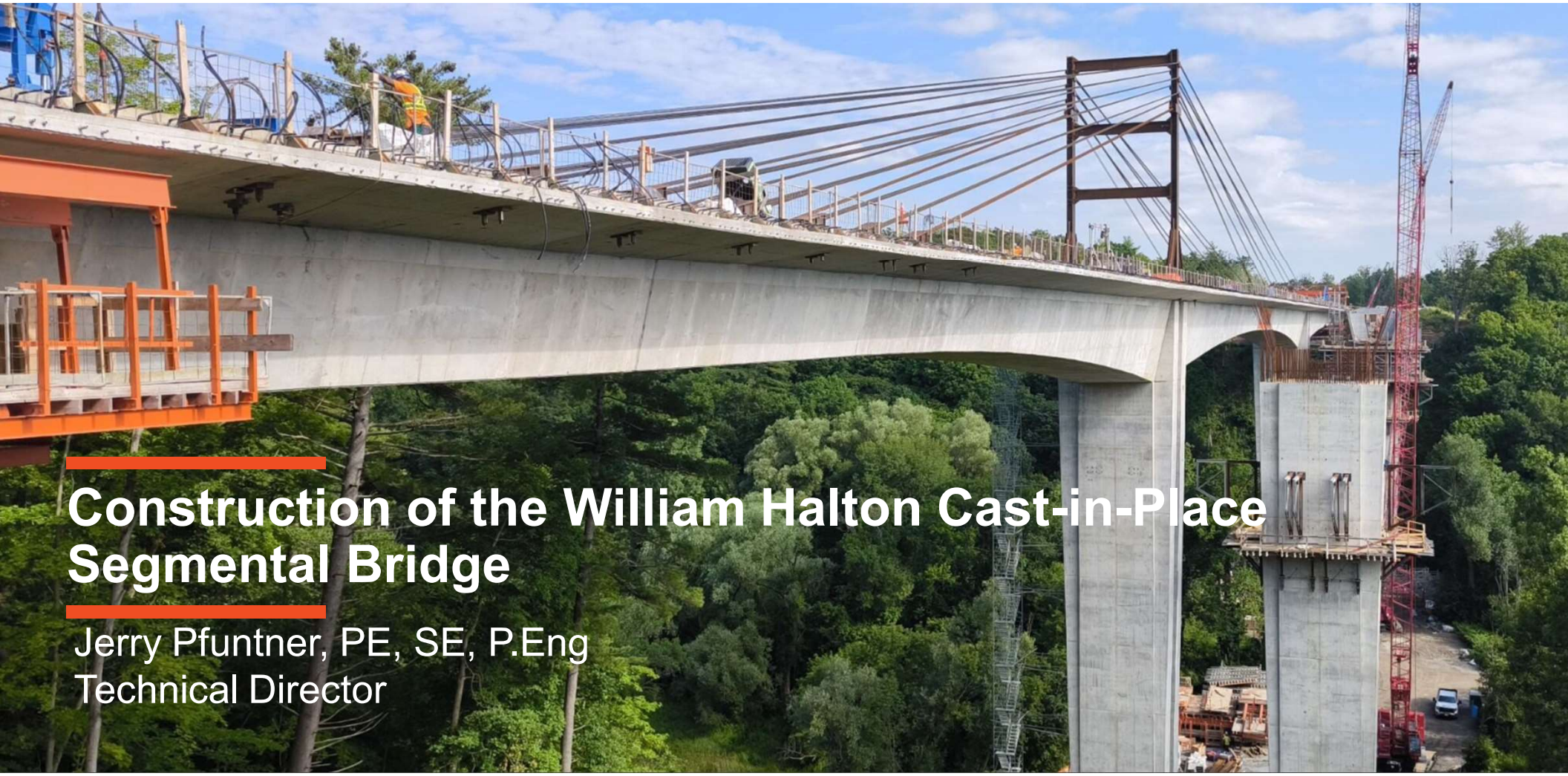


Construction of the William Halton Cast-in-Place Segmental Bridge

Jerry Pfuntner, PE, SE, P.Eng
Technical Director

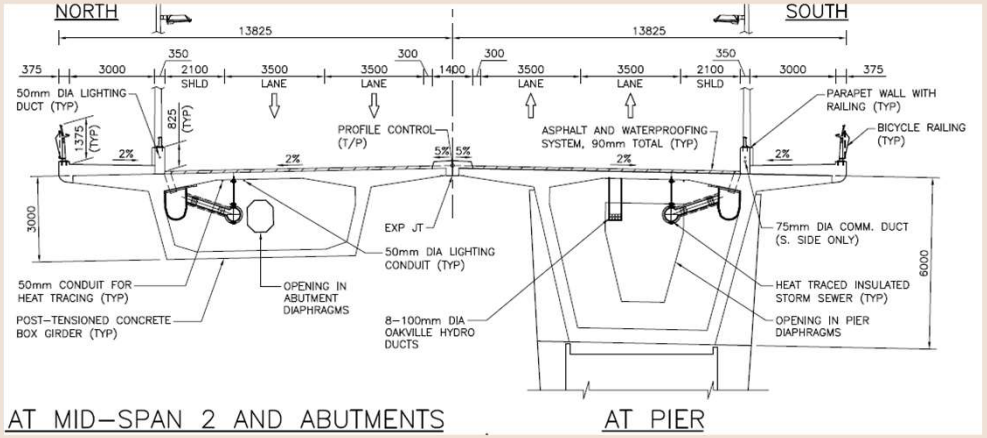
COWI

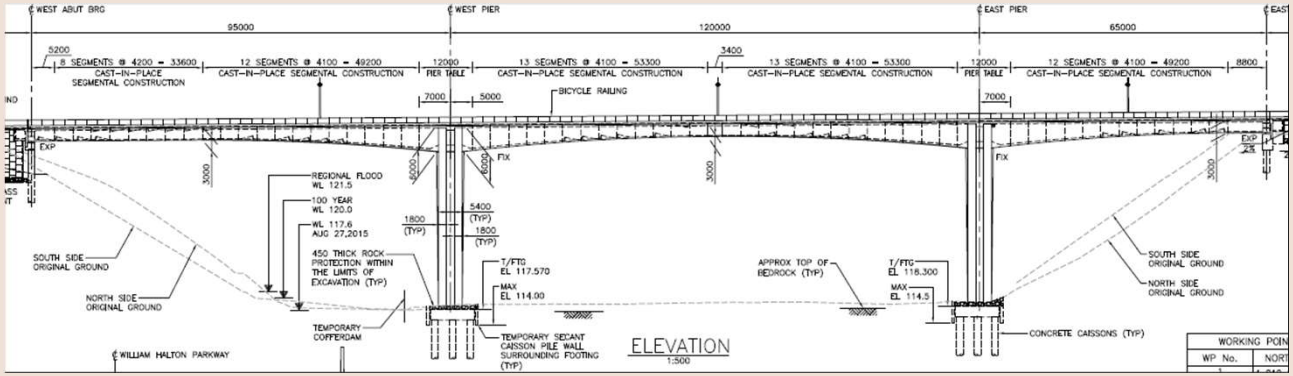
About the Project

- Located in Oakville, Ontario, CA near Toronto.
- Part of William Halton Parkway extension project.
- Expected completion in late 2025.
- Two new bridges over the 16 Mile Creek.
- Two lanes of traffic and pedestrian walkways.
- Will help ease traffic in rapidly growing area.
- **Owner is the Halton Region.**
- **Engineer of Record is WSP Canada.**
- **Contractor is BOT Construction.**
- **COWI is the Construction Engineer.**

Bridge Description

- 3-Span Segmental bridge.
- 95m – 120m – 65m span lengths.
- 38m Pier Heights.
- Box girder height of 3m to 6m.
- Box girder width of 14m.
- 90mm asphalt and waterproof layer.
- Two pier tables, 58 CIP segments, two end spans sections, and three closure segments.

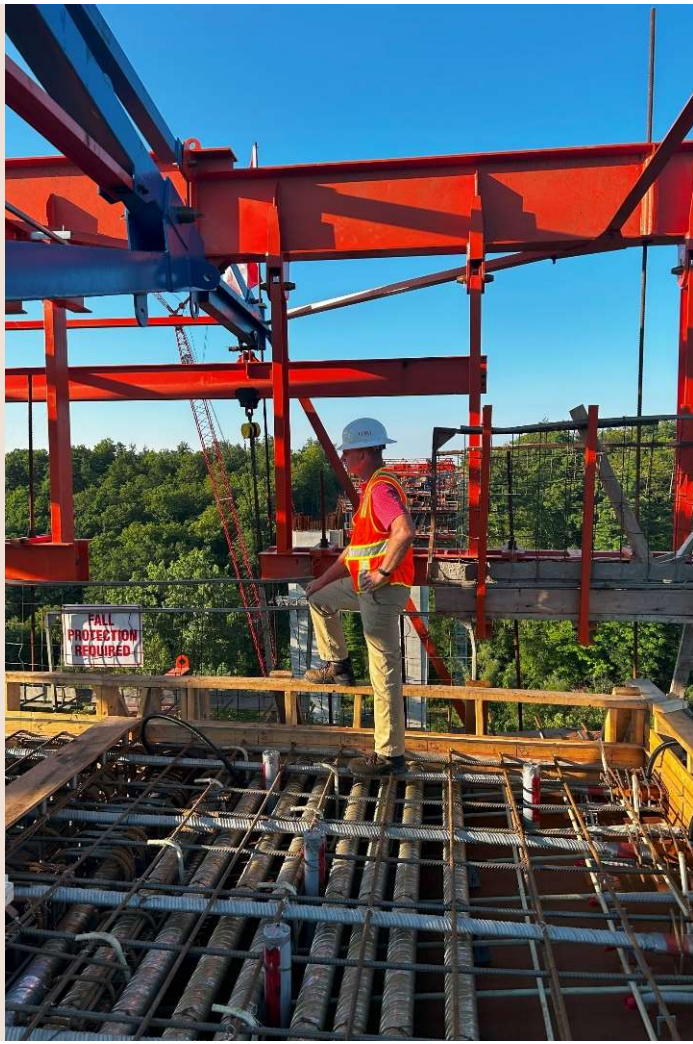




COWI’s Role

Scope of work:

- Staged construction analysis
- Erection and casting manuals
- Temporary works design
- Geometry control program
- Integrated Shop Drawings
- Construction support

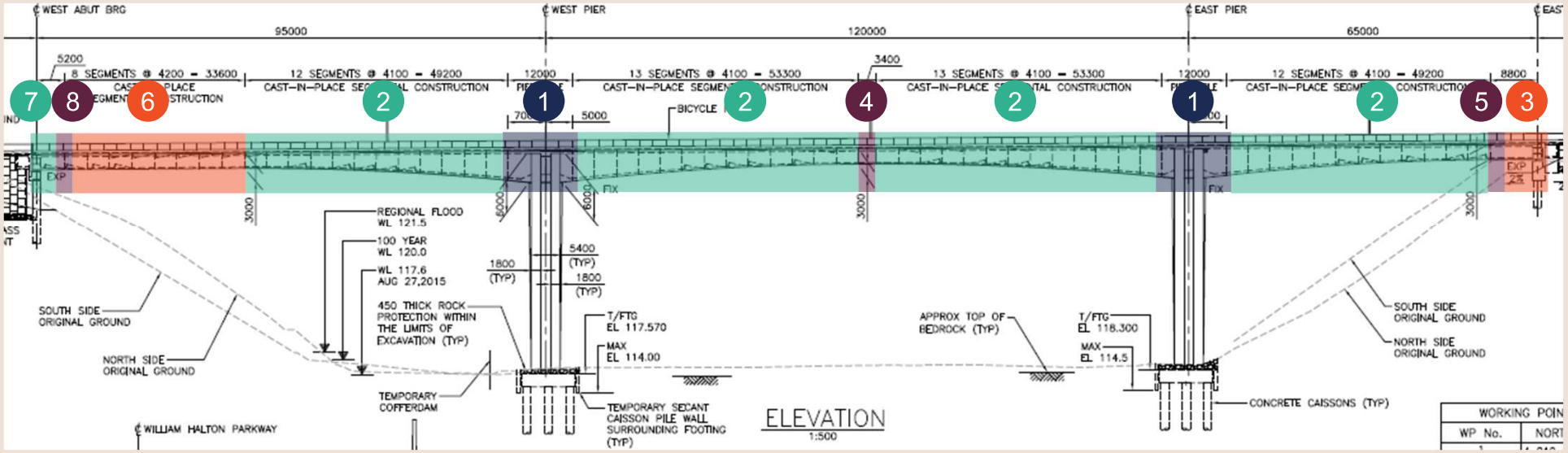


Construction Methodology

Overall Details for Constr.

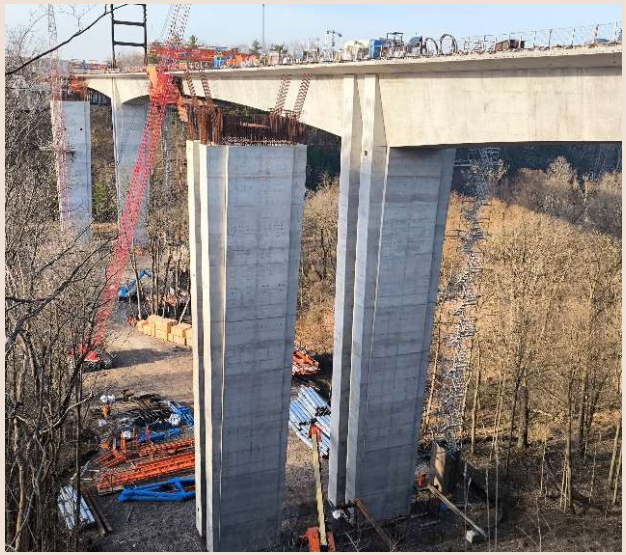
- Segmental cast-in-place balanced cantilever construction.
- 4 moveable form traveler (MFT) systems used at both cantilevers.
- ‘Extended’ cantilever on west pier constructed with MFT and temporary stay cable system.
- Shoring towers used for end span construction.
- COWI added closure segments from base design.

Superstructure Overall Sequence



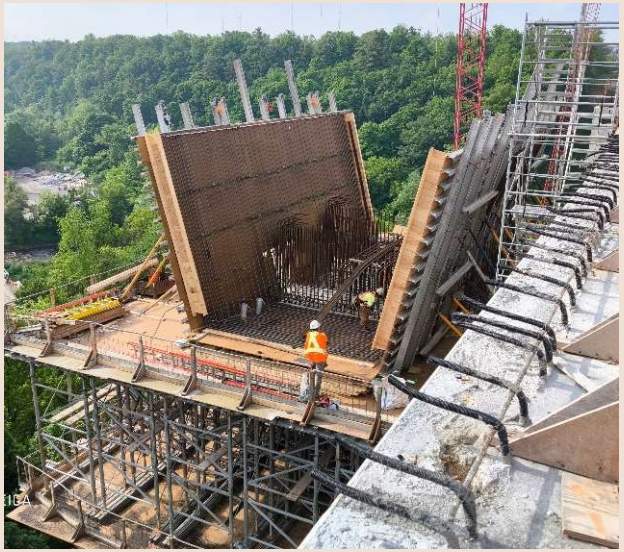

2
1
2
4
2
1
2
5
3

Substructure Construction



Pier Columns Constructed

Columns bars extended for Pier Table

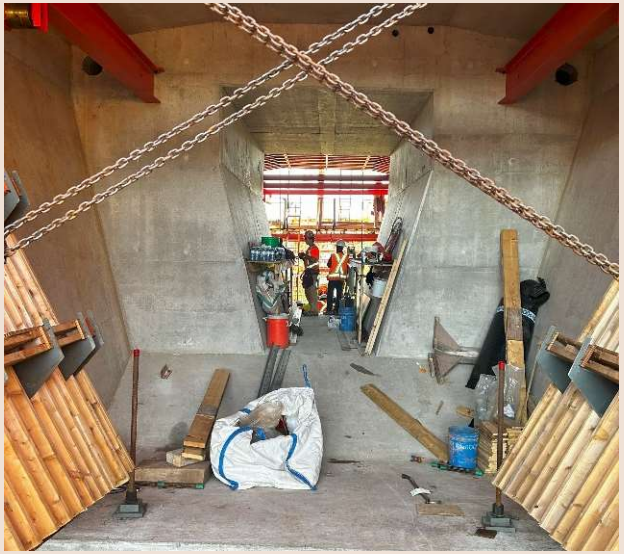


Installation of Formwork

Pier Table Construction

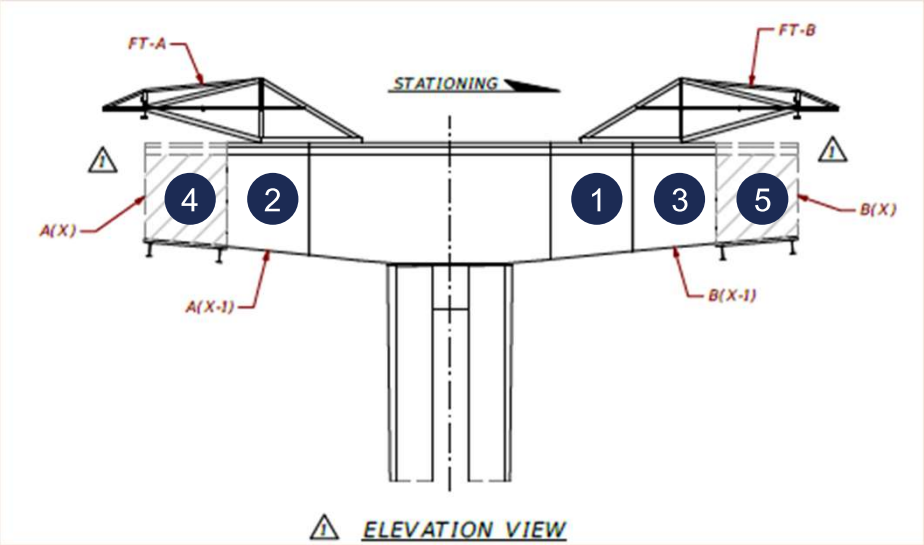
Casting of soffit and webs

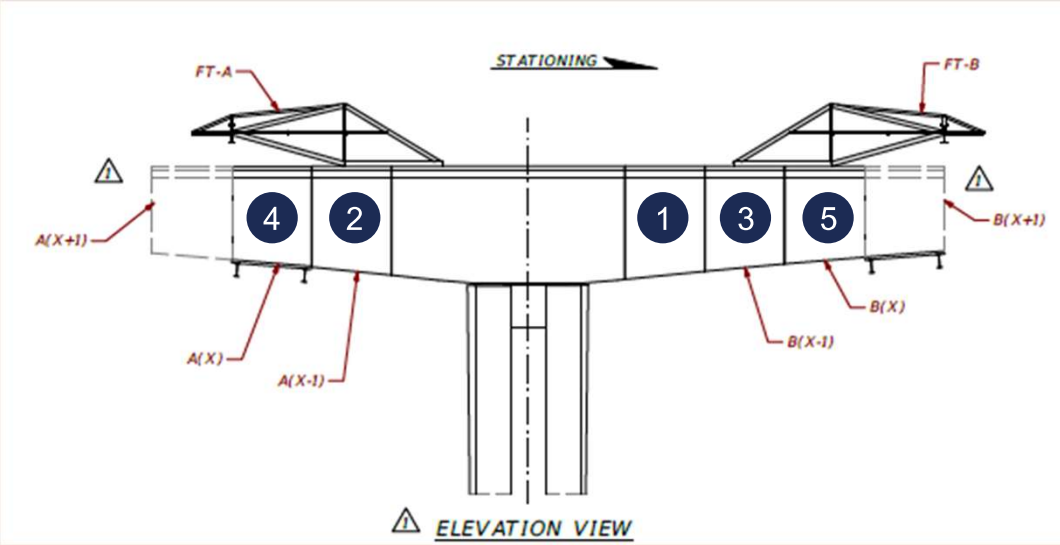
Casting of diaphragms



View of completed pier table

Typical Segment Cycle





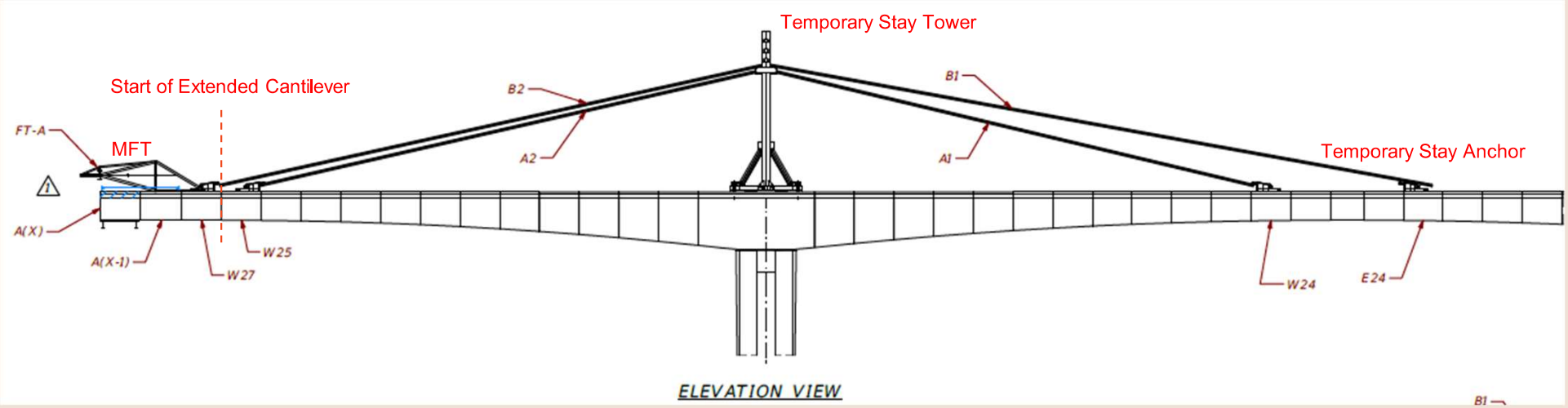
Typical Segment Cycle

Launch MFT forward and setup formwork

Install rebar, PT, inserts

Pour concrete

Extended Cantilever Cycle



Extended Cantilever Cycle (Stay + PT)

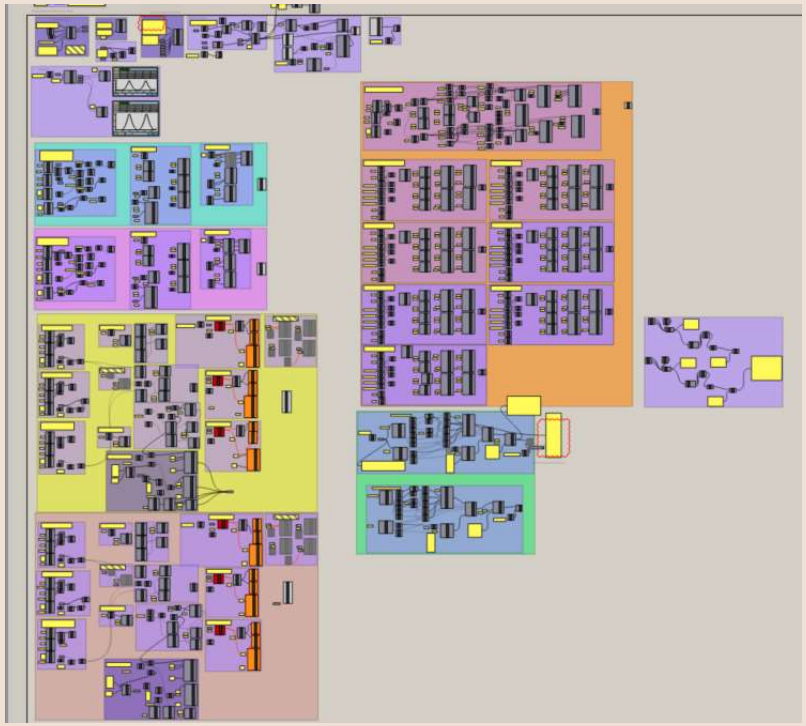
Uni-directional MFT construction

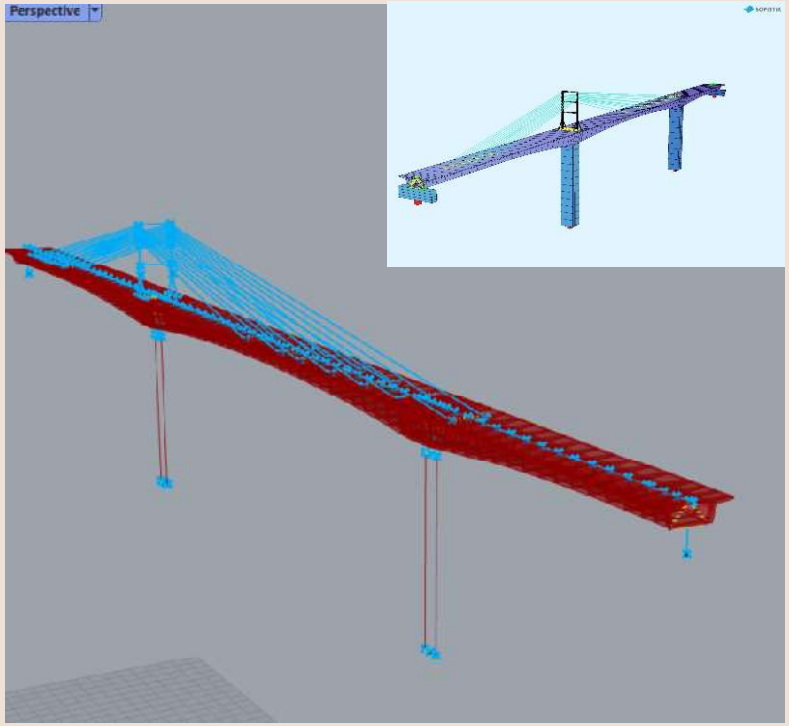
Temporary stay tower and anchors

External PT Bars and Brackets

Construction Analysis

LCA Model – Grasshopper to Sofistik





LCA Model – Post Tensioning Tendons

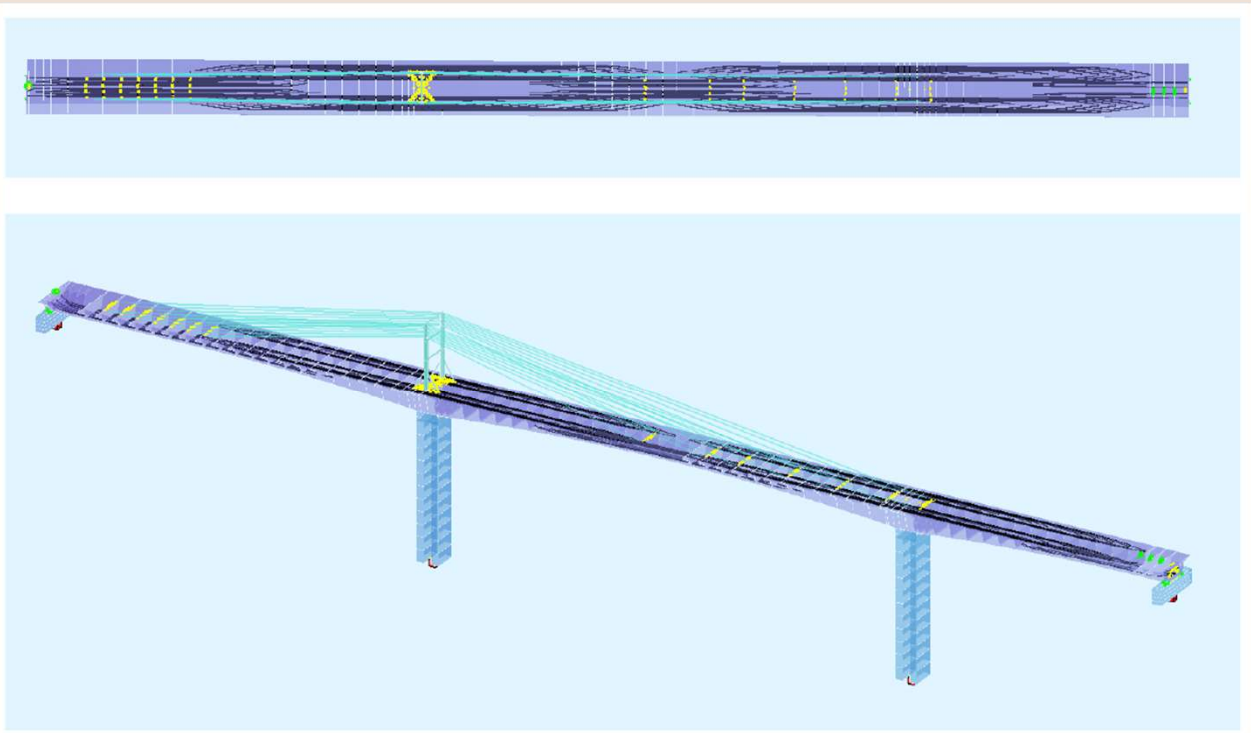
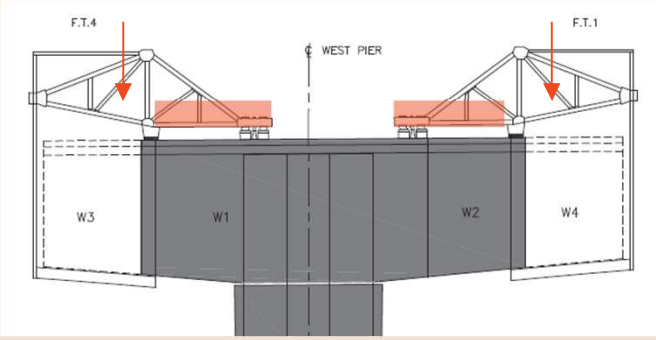


Figure 14: Cantilever and Bottom Tendon Layout

Loads and Load Combinations

CE – Construction Equipment	Form Traveler
CLL – Construction Live Load	500 Pa on one cantilever and 250 Pa on the other
IC – Ice Load during construction	Applied as a LL on the unbalance cantilever as per CAN
DIFF – Differential Self Weight	2% of the dead load applied to one cantilever
EL – Temporary Cable	Effects of temporary stay cable
WUP – Wind Uplift	5 psf on projected area of one cantilever
WE – Wind on Equipment	0.1 ksf of exposed surface
WS – Wind on Structure	10years return period as per 3.16.1

TU-Uniform Temperature Differential



2.5 Loads Combination

2.5.1 AASHTO Construction Load Combination

- Service Limit State (LRFD Table 5.12.5.3.3-1):
  - Combination b) c) d) ignored – equipment always present, and no segment unbalanced applied.
  - a) DC +EL+ DIFF + CLL + CEQ + IC + TU
  - d) DC +EL+ DIFF + CLL + CEQ + IC + TU + 0.7(WS) + WUP + 0.7(WE)
  - f) DC +EL+ CLL + CEQ + IC + TU + TG + 0.3(WS) + 0.3(WE)
- Construction Load Combinations at Strength Limit States (LRFD 5.12.5.3.4):
  - 1.1 (DC +DIFF) + EL+ 1.3(CEQ + CLL)
  - DC + CEQ
- Load Combinations at Strength Limit States (LRFD 3.4.1-1):
  - STR I: 1.25/0.9 (DC + DIFF+IC+CEQ) + EL + 1.5(CLL)+0.5/1.20(TU)
  - STR V (WS=80mph): 1.25/0.9 (DC + DIFF + IC + CEQ) + EL + 1.35(CLL) + 0.5/1.20(TU) + 1.0(WUP + WS + WE)

2.5.2 CAN Construction Load Combination

- Service Limit State (CAN Table 3.1):
  - SLS1 : DC + DIFF + EL + PS + 0.8(CR)+0.9(CLL) + CEQ + IC +0.8(TU)
- Construction Load Combinations at Strength Limit States (CAN Table 3.1):
  - ULS1: 1.20/0.9(DC + DIFF + CEQ + IC) + EL + 1.05/0.95(PS) + 0.85*1.70(CLL)
  - ULS2: 1.20/0.9(DC + DIFF + CEQ + IC) + EL + 1.05/0.95(PS) + 0.85*1.60(CLL) + 1.15(TU+CR)
  - ULS3: 1.20/0.9(DC + DIFF + CEQ + IC) + EL + 1.05/0.95(PS) + 0.85*1.40(CLL) + 1.0(TU + CR) + 0.45(WS + WE) + WUP

Construction Staging

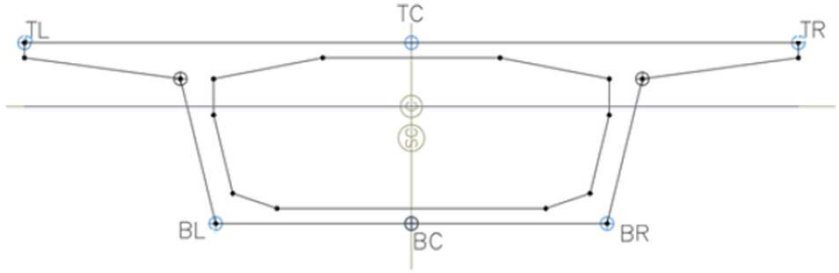
- All stages of construction are modeled to capture worst-case effects.
- Targeted geometry control stages are also required for staging.
- Moving permanent loads such as MFT are modeled with application and removal stages.
- Creep and shrinkage effects are captured and synced with construction schedule.
- Temporary fixities and potential locked-in forces due to structural configuration changes are captured.

Construction Stages

CS	Type	t [d]	RH [%]	T [°C]	laun_1 [m]	laun_2 [m]	Designation
1000	D_1						WEST ABUTMENT
1010	D_1						WEST PIER & EAST PIER
1030	D_1						EAST ABUTMENT
1035	C_1	129	70	15			EAST AND WEST PIER CS
1040	D_4						DUMMY D_4
1050	D_4						DUMMY D_3
3010	D_1						W1 ERECT
3020	PS						PS 1-C1
3030	C_1	54	70	15			W1 CS + W2 CAST
3095	D_3						FT ERECT W2
3100	D_1						W2 ERECT
3120	PS						PS 1-C2
3130	C_1	7	70	15			W2 CS + W3 CAST
3195	D_3						FT ERECT W3&W4
3200	D_1						W3 ERECT
3205	C_1	7	70	15			W3 CS + W4 CAST
3210	D_1						W4 ERECT
3220	PS						PS 1-C3 & PS 1-C4
3230	C_1	7	70	15			W4 CS + W5 CAST
3295	D_3						FT ERECT W5&W6
3300	D_1						W5 ERECT
3305	C_1	7	70	15			W5 CS + W6 CAST
3310	D_1						W6 ERECT
3320	PS						PS 1-C5
3330	C_1	7	70	15			W6 CS + W7 CAST
3395	D_3						FT ERECT W7&W8
3400	D_1						W7 ERECT
3405	C_1	7	70	15			W7 CS + W8 CAST
3410	D_1						W8 ERECT
3420	PS						PS 1-C6 & PS 1-C7

Superstructure Longitudinal Stresses

Deck stress points are established at top and bottom extreme fiber of the deck cross-section.



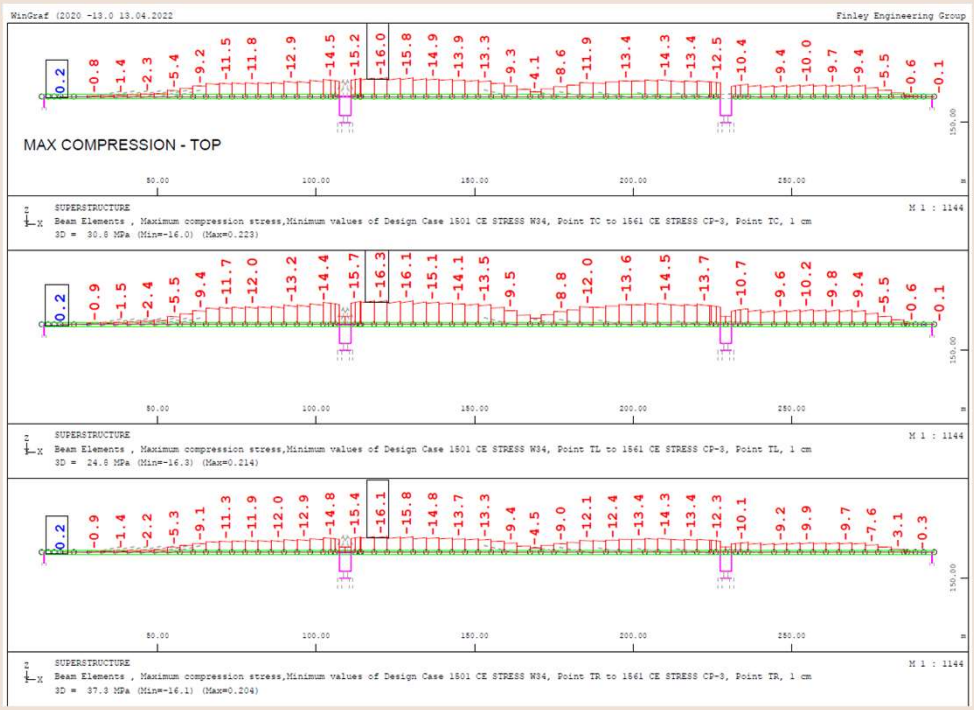
Maximum Stresses during Construction

Per CAN Section 8.8.4.6a-ii, tensile stresses within the superstructure can be taken by the uncracked concrete tensile capacity up to a stress of 1.41 MPa at 50MPa for normal weight concrete for non-segmental joints only.

Within the following plot, the maximum tensile stress during construction is:

- 0.98 MPa (TC) within the Pier 1 Pier Table
- 1.0 MPa (TL) within West end span segment
- 1.12 MPa (TR) within middle Span

Maximum compressive stresses during construction is 23.5 MPa (Bot) and is well within the limitation of 0.6xF'ci = 30MPa as per CAN Section 8.8.4.6.



Construction Modifications

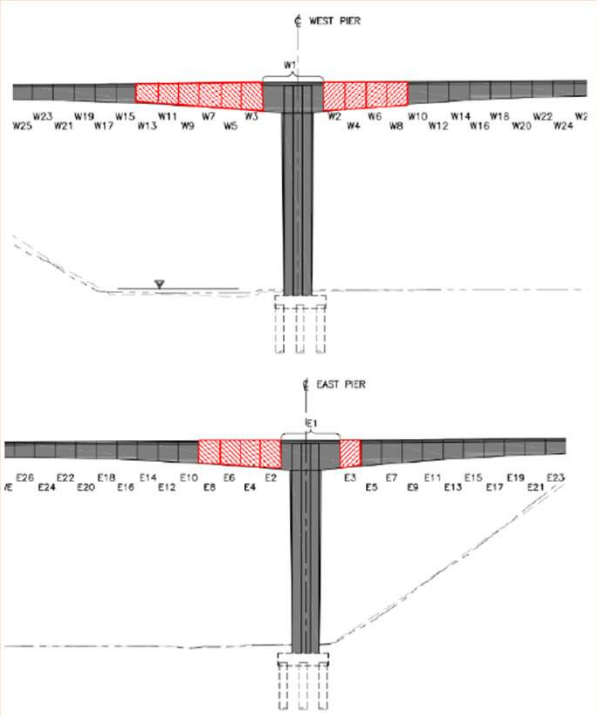


Figure 15: Segments that required web reinforcement modification

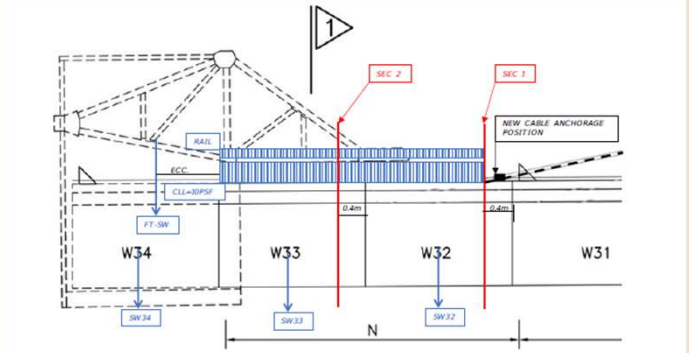


Figure 16: Loading Condition 1- Casting of Segment W34

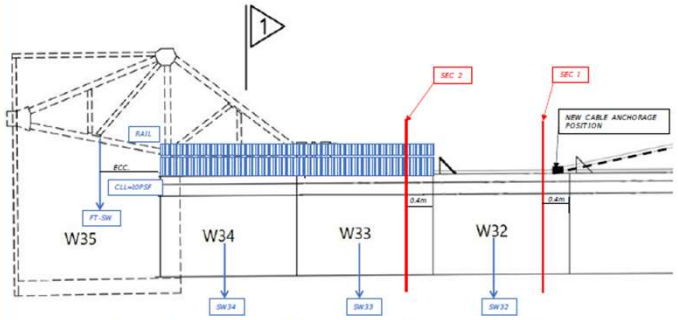


Figure 17: Loading Condition 2- Launching of MFT for Casting of West Closure

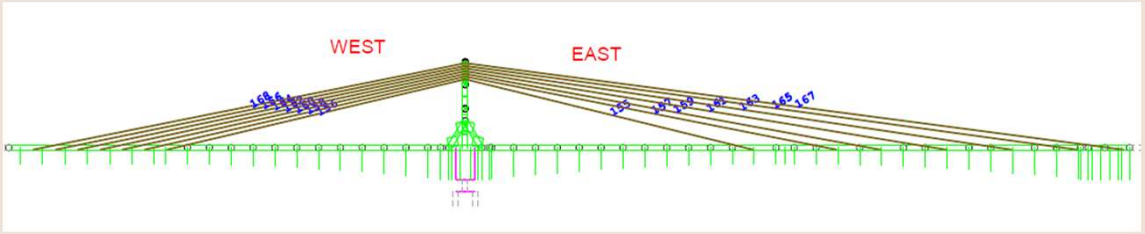
Modifications:

1. Increase of Web reinforcement for shear capacity near piers.
2. Increase of top slab longitudinal rebar for negative moment.
3. Increase of top slab rebar beyond stay cables.

Causes:

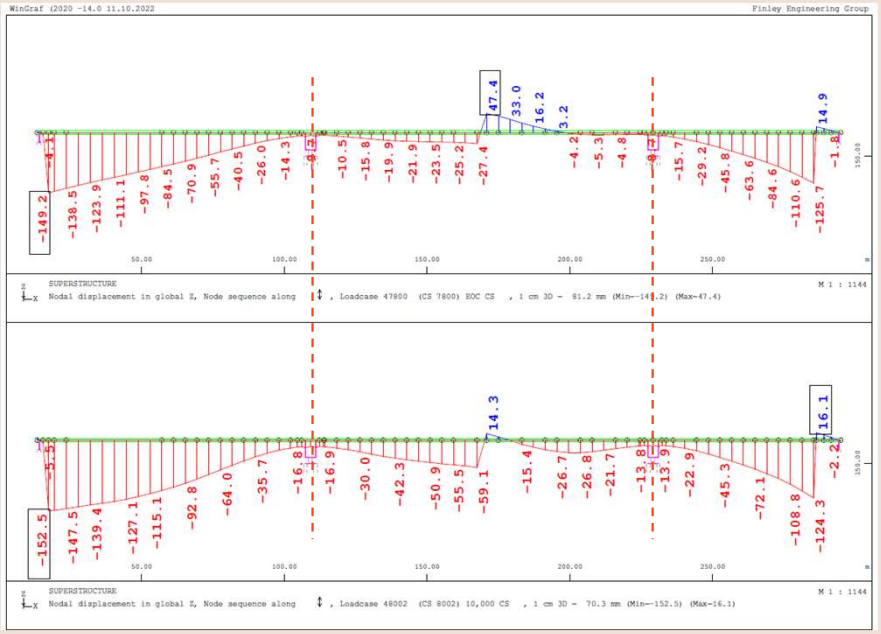
1. Unbonded cantilever tendons during construction.
2. Increase in loads during construction.

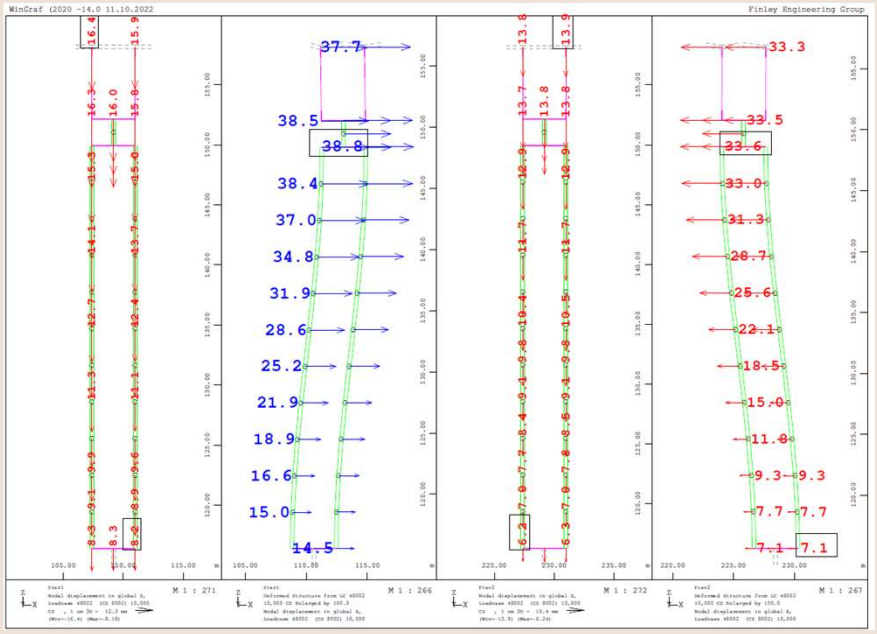
Temporary Stay Cable Analysis



STAGE	CABLE	CABLE AXIAL FORCE [KN]							
		WEST			EAST			DIFFERENCE	
		GRP	RIGHT	LEFT	GRP	RIGHT	LEFT	RIGHT	LEFT
CABLE A ERECT	A	156	2900.0	2900.0	155	2900.0	2900.0	0.0	0.0
W28 ERECT	A	156	2906.1	2906.2	155	2902.1	2902.1	-4.0	-4.1
CABLE B ERECT	A	156	2898.4	2898.4	155	2895.0	2895.0	-3.4	-3.4
	B	158	2900.0	2900.0	157	2900.0	2900.0	0.0	0.0
W29 ERECT	A	156	2904.7	2904.8	155	2897.7	2897.7	-7.0	-7.1
	B	158	2906.6	2906.6	157	2902.7	2902.7	-3.9	-3.9
CABLE C ERECT	A	156	2897.0	2897.0	155	2890.0	2889.9	-7.0	-7.1
	B	158	2898.5	2898.5	157	2895.6	2895.6	-2.9	-2.9
	C	160	2900.0	2900.0	159	2900.0	2900.0	0.0	0.0
W30 ERECT	A	156	2903.4	2903.5	155	2893.2	2893.2	-10.2	-10.3
	B	158	2905.3	2905.4	157	2898.9	2898.9	-6.4	-6.5
	C	160	2907.1	2907.2	159	2903.3	2903.3	-3.8	-3.9
CABLE D ERECT	A	156	2895.9	2895.9	155	2884.8	2884.7	-11.1	-11.2
	B	158	2897.4	2897.4	157	2891.0	2891.0	-6.4	-6.4
	C	160	2898.9	2898.9	159	2895.6	2895.6	-3.3	-3.3
	D	162	2900.0	2900.0	161	2900.0	2900.0	0.0	0.0
W31 ERECT	A	156	2902.5	2902.6	155	2888.6	2888.6	-13.9	-14.0
	B	158	2904.5	2904.5	157	2894.8	2894.8	-9.7	-9.7
	C	160	2906.3	2906.4	159	2899.4	2899.4	-6.9	-7.0
	D	162	2907.8	2907.8	161	2903.7	2903.7	-4.1	-4.1
CABLE E ERECT	A	156	2895.1	2895.1	155	2879.6	2879.5	-15.5	-15.6
	B	158	2896.5	2896.5	157	2886.4	2886.4	-10.1	-10.1
	C	160	2897.9	2898.0	159	2891.1	2891.1	-6.8	-6.9
	D	162	2899.0	2899.0	161	2895.9	2895.9	-3.1	-3.1
	E	164	2900.0	2900.0	163	2900.0	2900.0	0.0	0.0
	A	156	2903.1	2903.1	155	2885.0	2885.0	-18.1	-18.1

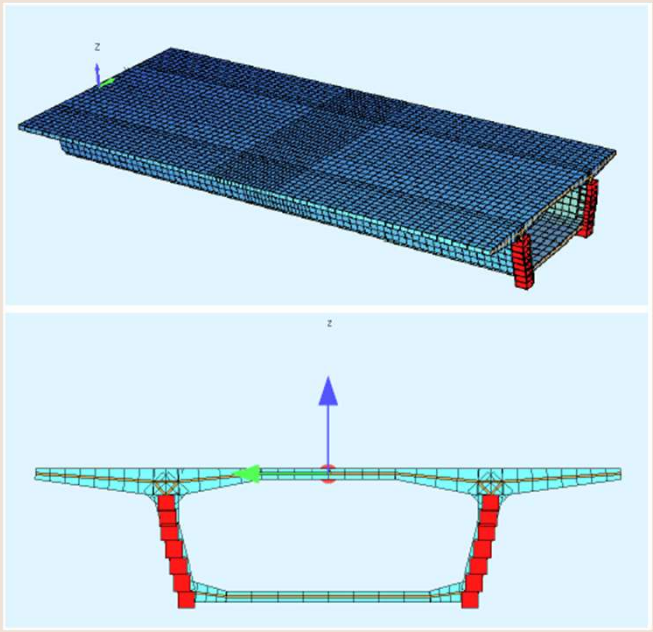
Bridge Camber



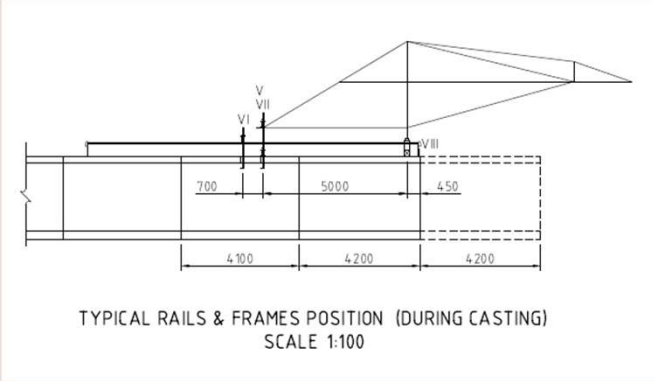


Transverse Construction Analysis TCA

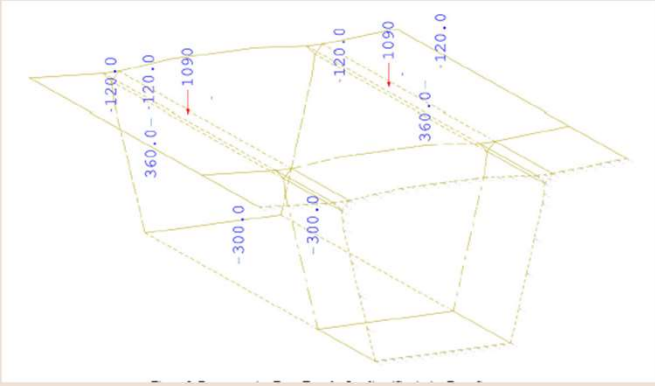
- Local Checks for:
  - Cranes on Deck
  - Moveable Form Traveler
  - Concentrated Forces
  - PT Tendons
- Transverse bending stresses
- Punching Shear

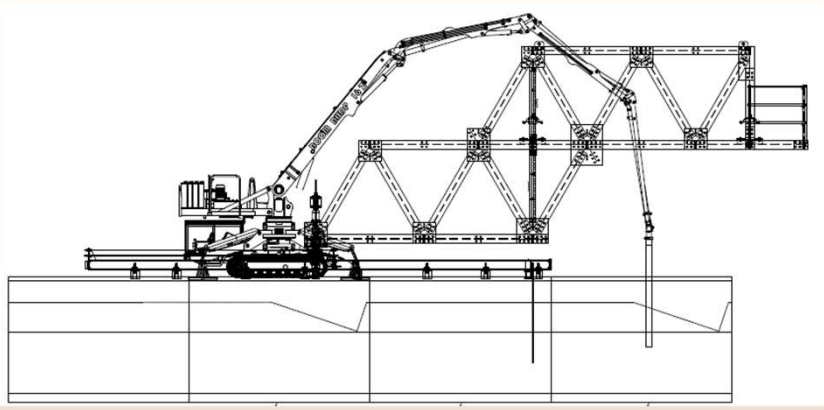


Load Applications



TYPICAL RAILS & FRAMES POSITION (DURING CASTING)
SCALE 1:100





SPYDER FLYER BOOM CRANE - TOTAL WEIGHT = 116 KN, 4570x4570 OUTRIGGER SPACING (PICKING CONDITION)

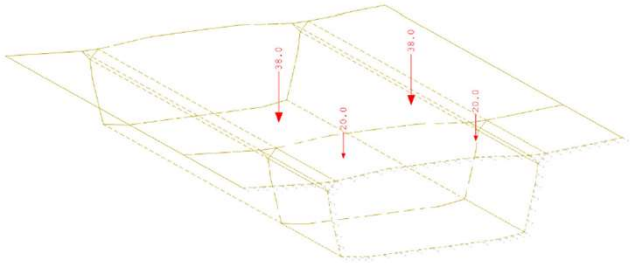


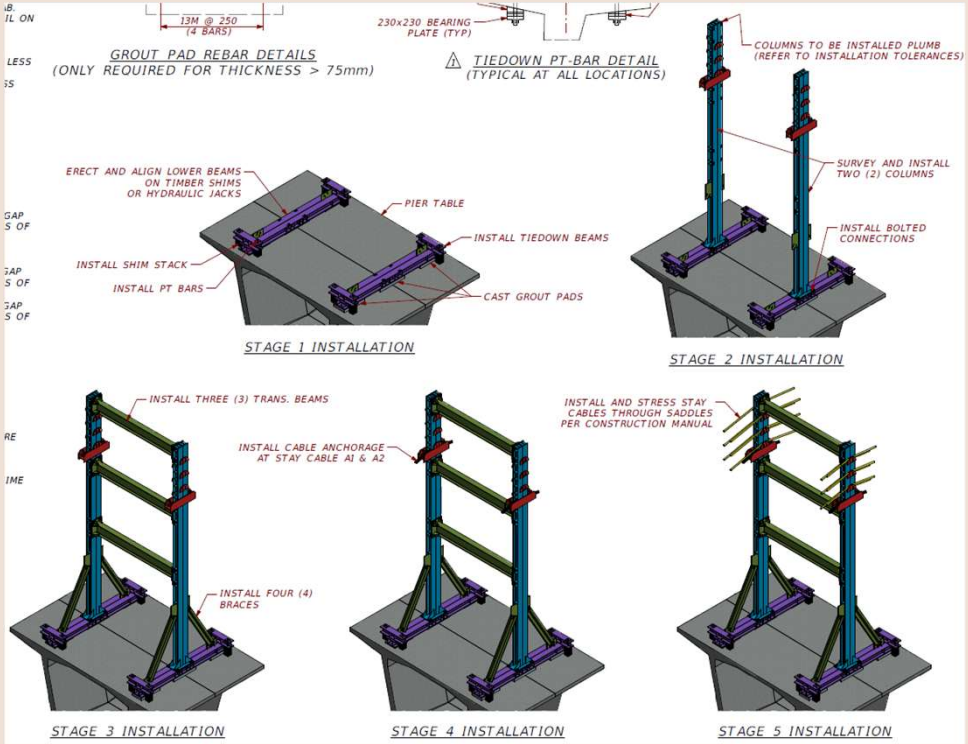
Figure 12: Representative Crane Near CL Superstructure Loading

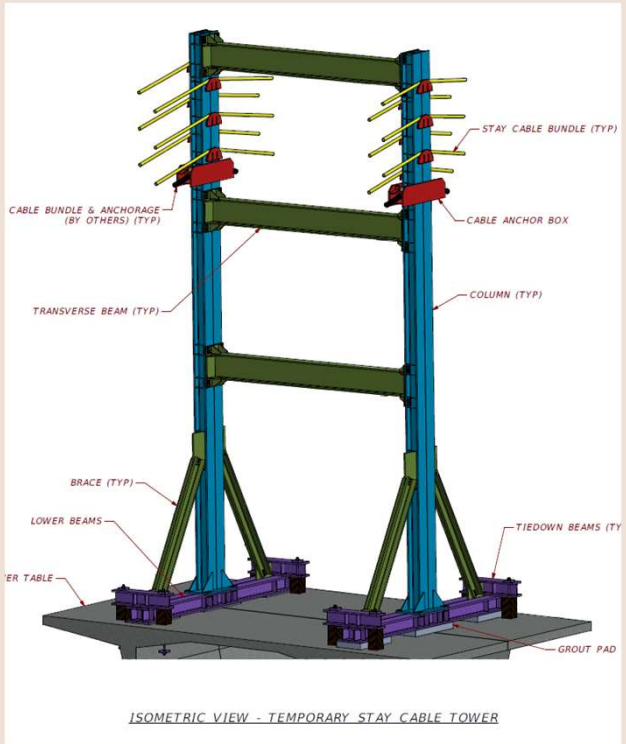
Temporary Works

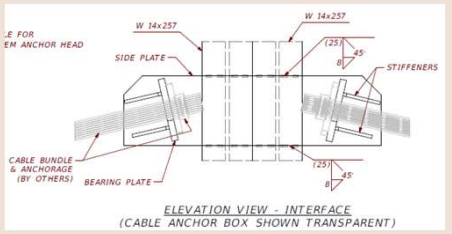
Temporary Stay Tower

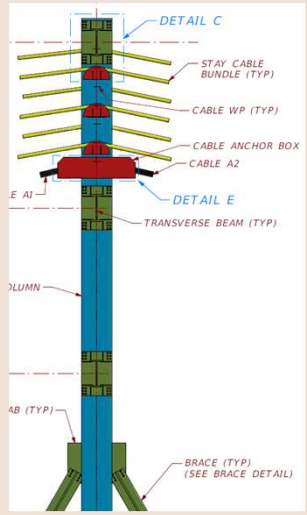
- Required for extended cantilever construction.
- Applies external axial forces to segments that do not have cantilever PT tendons.
- Fixed connection at pier table.
- Stays greatly affected geometry control under temperature.

Temporary Stay Tower Design









Temporary Stay Tower

View of stay tower facing away from extended cantilever

Layout of stay cables along extended cantilever

Temporary Stay Tower

Grout pads & base connection to pier table

Bracing and base elements of tower

Columns and transverse beams of tower

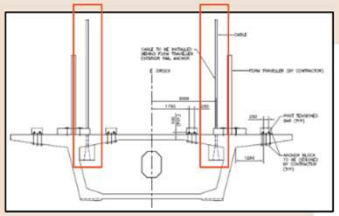
Temporary Stay Tower

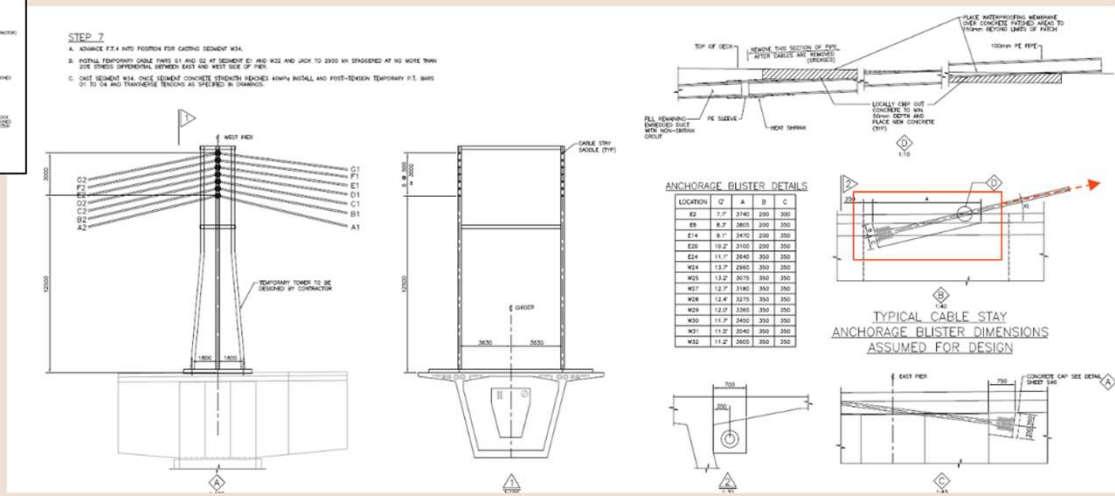
A1/A2 anchor points on tower

View of anchoring stay cable

Saddle detail for typical stay

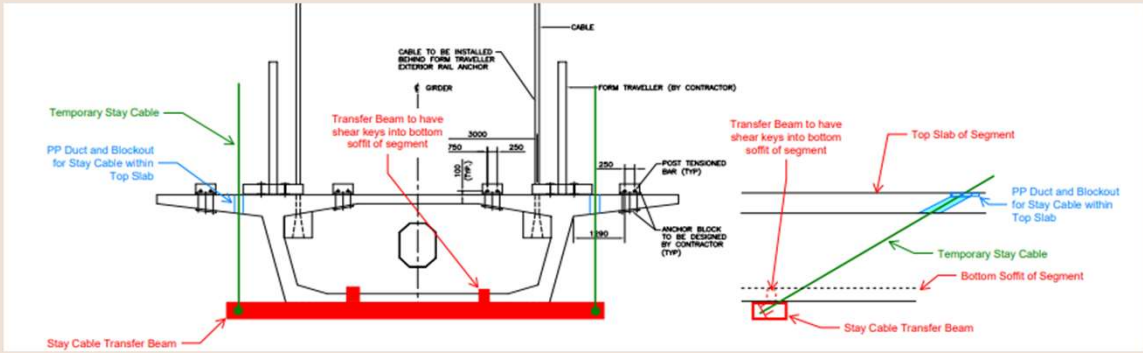
Cable Anchor Boxes





Contract Plan Design:

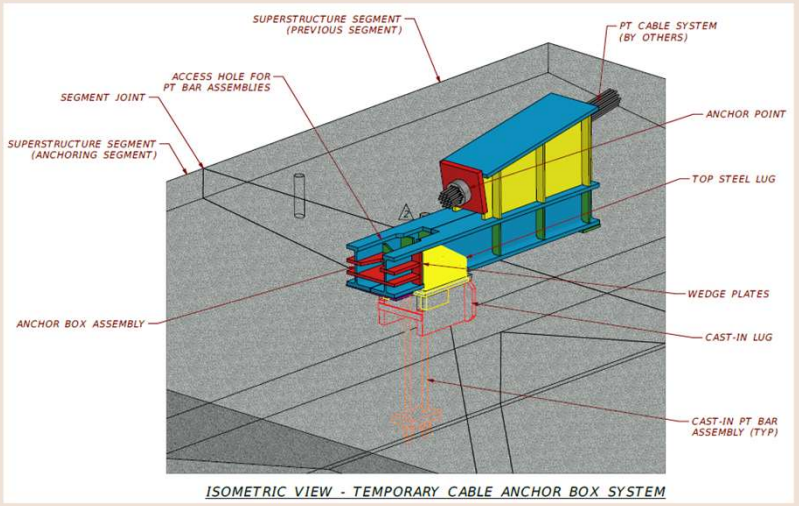
External Anchorage Concept:



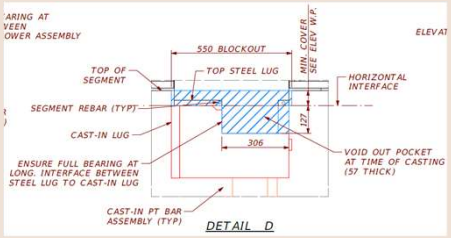
Cable Anchor Boxes

- Alternative detail from Plans which had anchorage details thru top slab that needed pourback.
- Major elements: Cast-in lug, vertical web PT, and upper weldment.
- Clashes need to be resolved for stressing jack, MFT location, and cast-in details against rebar cage.

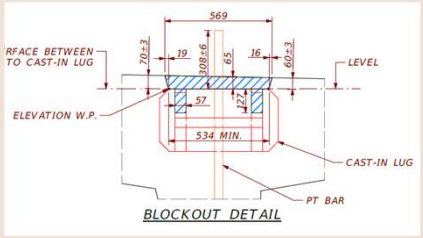
Cable Anchor Box Design



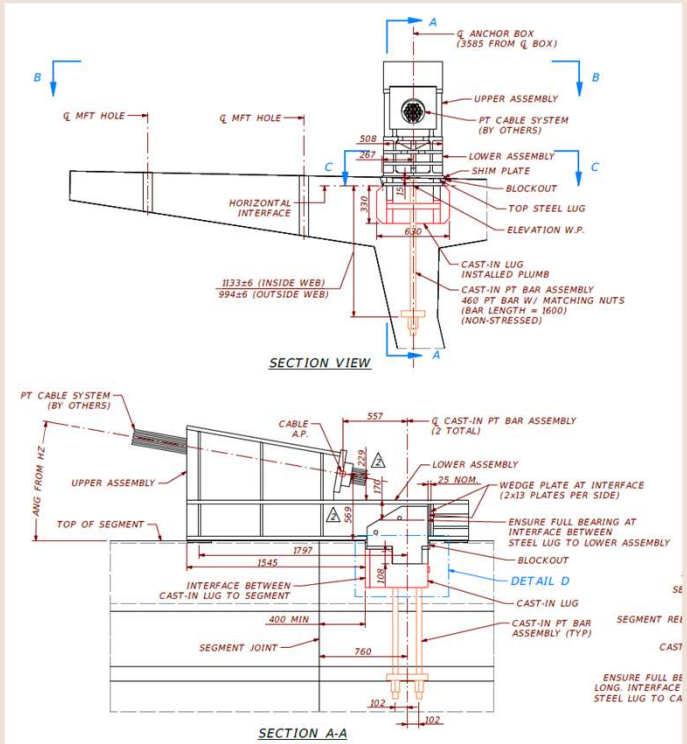
ISOMETRIC VIEW - TEMPORARY CABLE ANCHOR BOX SYSTEM



DETAIL D

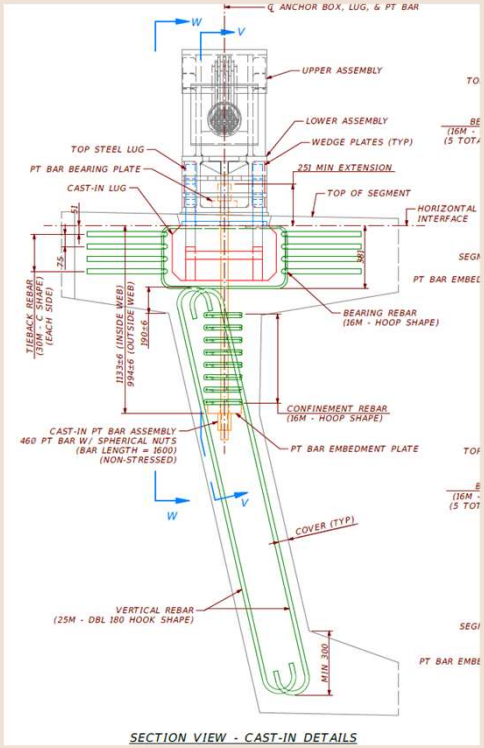


BLOCKOUT DETAIL



SECTION VIEW

SECTION A-A



SECTION VIEW - CAST-IN DETAILS

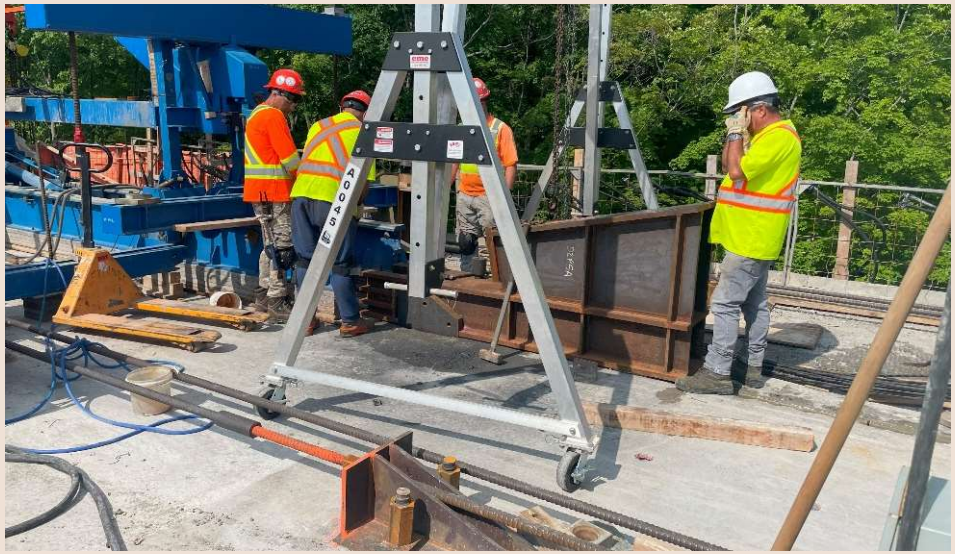
Cable Anchor Box Anchorage

Cable Anchor Boxes

Arrangement on Extended cantilever

Anchor box fitted between MFT rails

Cable Anchor Boxes



Installation of anchor box

Interface of cast-in lug to anchor box

Cable Anchor Boxes

Mono-strand stressing jack fitted on anchor box

Stay cable path from anchor box to stay tower

Geometry Control

Geometry Control - Typical

1st Critical Stage – MFT Setup prior to concrete pour

(assume MFT local deflection under wet concrete)

2nd Critical stage – After concrete casting

(finding out where the MFT 'landed')

Geometry Control Program

Select Construction Stage:

PT BARS L INSTALL
Set-Up W32
CABLE E INSTALL
W32 AFTER CAST
PT BARS M INSTALL
Set-Up W33
CABLE F INSTALL
W33 AFTER CAST
PT BARS N INSTALL
Set-Up W34
CABLE G INSTALL
W34 AFTER CAST

Save Erection Elevation Data

Stage Name: PT BARS N INSTALL
Add Suffix to Save Data File: _072224
Time of Survey: 0:00
Temperature of Survey: -- C

Project: William Halton Pkwy
Project No.: 20.60541
Author: Junfeng Li, P.E.

Revision Log:

Rev. #	Date	Description
0	5/6/2024	Initial

Notes:
1) Elevation is provided at CL Girder.
2) Only leading tip of CIP on FW segments provided.
3) O = Set-Up Phase, X = After-Cast Phase
4) See Figure for "A", "C", and "E" locations.
5) Offset "Left" or "Right" facing direction of casting.
6) Camber values based on LCA Rev.0 at "10k Days".
7) All values provided in meter units.

SOUTH BRIDGE

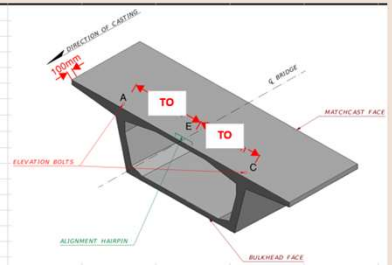
FINLEYcip Inputs:

See 'Survey Bolt Inputs'	= Transverse Offset from Centerline of Segment to A & C [m]
	= Longitudinal Offset from End of Segment to Hairpins [m]
	= Vertical Offset of Hairpins from Deck Surface from Top of Deck [m]
-0.0150	= MFT-W of West Cantilever Deflection at Bulkhead [m]
-0.0150	= MFT-E of West Cantilever Deflection at Bulkhead [m]
-0.0150	= MFT-W of East Cantilever Deflection at Bulkhead [m]
-0.0150	= MFT-E of East Cantilever Deflection at Bulkhead [m]

Per Contract Plans:

0.050	= Northing/Easting Bridge Angle [rad]
0.700	= Bridge Grade [%]
2.000	= Bridge Superelevation [%]

Reference Documents:
1. FINLEY Geometry Control Manual
2. FINLEY Construction Manual
3. NRS Form Traveler Drawings and Operations Manual



West Abutment: CIP on Falsework (Leading Edge)

W Abut Bearing Station = 13+134.19 W Abut Bearing Chainage = -95.00

Survey Pt.	Segment	Chainage	Station	CL Elev.[1]	Casted[3]	Superstructure Erection Elevations: Theoretical[6] Elevation A[4]	Theoretical[6] Elevation C[4]	Theoretical[6] Station E	Theoretical[6] Offset	Actual Elevation A[4]	Actual Elevation C[4]	Actual Station E	Actual Offset	Differential = [Actual - Theoretical] Elevation A[4]	Differential = [Actual - Theoretical] Elevation C[4]	Differential = [Actual - Theoretical] Station E	Differential = [Actual - Theoretical] Offset Left or Right[5]
S-EB-1	EB-1	153.7	13+135.49	158.650													

West Pier Cantilever: CIP on Falsework & CIP w/ MFT

Notes:

Survey Pt.	Segment	Chainage	Station	CL Elev.[1]	Casted[3]	Superstructure Erection Elevations: Theoretical[6] Elevation A[4]	Theoretical[6] Elevation C[4]	Theoretical[6] Station E	Theoretical[6] Offset	Actual Elevation A[4]	Actual Elevation C[4]	Actual Station E	Actual Offset	Differential = [Actual - Theoretical] Elevation A[4]	Differential = [Actual - Theoretical] Elevation C[4]	Differential = [Actual - Theoretical] Station E	Differential = [Actual - Theoretical] Offset Left or Right[5]
S-W34	W34	149.80	13+139.39	158.677													
S-W33	W33	145.60	13+143.59	158.707	X	158.872	158.752	13+143.69	0.000								
S-W32	W32	141.40	13+147.79	158.736	X	158.900	158.780	13+147.89	0.000								
S-W31	W31	137.20	13+151.99	158.765	X	158.928	158.808	13+152.09	0.000								
S-W30	W30	133.00	13+156.19	158.795	X	158.956	158.836	13+156.29	0.000								
S-W29	W29	128.80	13+160.39	158.824	X	158.984	158.864	13+160.49	0.000								
S-W28	W28	124.60	13+164.59	158.854	X	159.009	158.889	13+164.69	0.000								
S-W27	W27	120.40	13+168.79	158.883	X	159.033	158.913	13+168.89	0.000								
S-W25	W25	116.20	13+172.99	158.912	X	159.056	158.936	13+173.09	0.000								
S-W23	W23	112.10	13+177.09	158.941	X	159.077	158.957	13+177.19	0.000								
S-W21	W21	108.00	13+181.19	158.970	X	159.097	158.977	13+181.29	0.000								
S-W19	W19	103.90	13+185.29	158.998	X	159.118	158.998	13+185.39	0.000								
S-W17	W17	99.80	13+189.39	159.027	X	159.139	159.019	13+189.49	0.000								
S-W15	W15	95.70	13+193.49	159.056	X	159.160	159.040	13+193.59	0.000								
S-W13	W13	91.60	13+197.59	159.085	X	159.183	159.063	13+197.69	0.000								
S-W11	W11	87.50	13+201.69	159.113	X	159.205	159.085	13+201.79	0.000								
S-W9	W9	83.40	13+205.79	159.142	X	159.228	159.108	13+205.89	0.000								
S-W7	W7	79.30	13+209.89	159.171	X	159.251	159.131	13+209.99	0.000								
S-W5	W5	75.20	13+213.99	159.199	X	159.275	159.155	13+214.09	0.000								
S-W3	W3	71.10	13+218.09	159.228	X	159.299	159.179	13+218.19	0.000								
S-W1w	W1w	67.00	13+222.19	159.257	X	159.325	159.205	13+222.29	0.000								
S-P-1	P-1	60.00	13+229.19	159.305	X	159.372	159.252	13+229.29	0.000								
S-W1e	W1e	55.00	13+234.19	159.339	X	159.286	159.406	13+234.09	0.000								

Survey Bolt Inputs*

Segment	Trans Offset	Long Offset	Vert Offset
EB-1	3.000	0.100	0.000

*May be average of East and West bolt values.

Survey Bolt Inputs*

Segment	Trans Offset	Long Offset	Vert Offset
W34	3.000	0.100	0.000
W33	3.000	0.100	0.000
W32	3.000	0.100	0.000
W31	3.000	0.100	0.000
W30	3.000	0.100	0.000
W29	3.000	0.100	0.000
W28	3.000	0.100	0.000
W27	3.000	0.100	0.000
W25	3.000	0.100	0.000
W23	3.000	0.100	0.000
W21	3.000	0.100	0.000
W19	3.000	0.100	0.000
W17	3.000	0.100	0.000
W15	3.000	0.100	0.000
W13	3.000	0.100	0.000
W11	3.000	0.100	0.000
W9	3.000	0.100	0.000
W7	3.000	0.100	0.000
W5	3.000	0.100	0.000
W3	3.000	0.100	0.000
W1	3.000	0.100	0.000
P1	3.000	0.100	0.000
W1	3.000	0.100	0.000

Geometry Control – Thermal effects

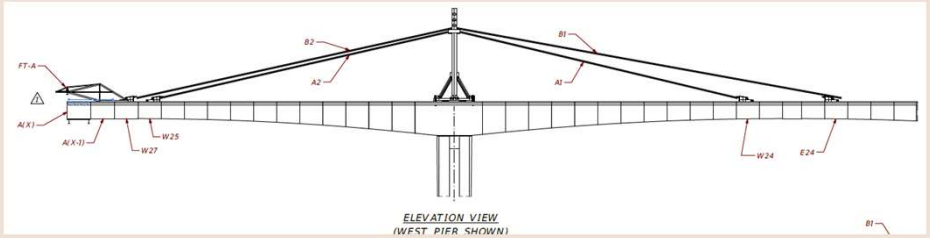
Modified Deck Surveying procedures for the extended cantilever segments:

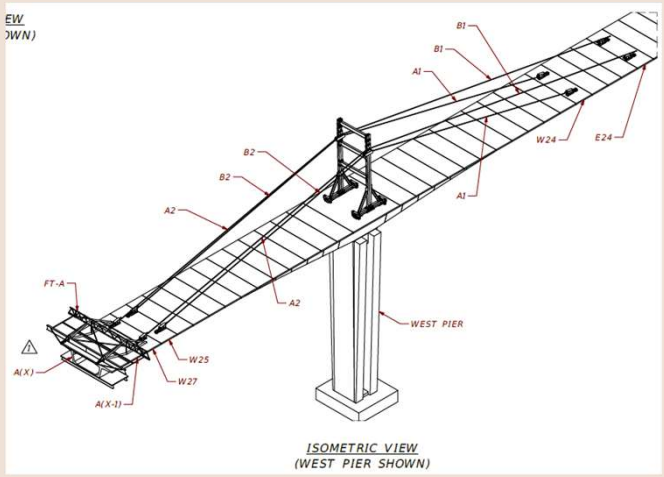
1. Typical first light survey
2. Afternoon surveys repeatedly to track thermal deflections vs. ambient temperature
3. Segment setups based on theoretical construction displacements & thermal correction

Transition from Spring to Summer brought wild swings in daily temperatures:

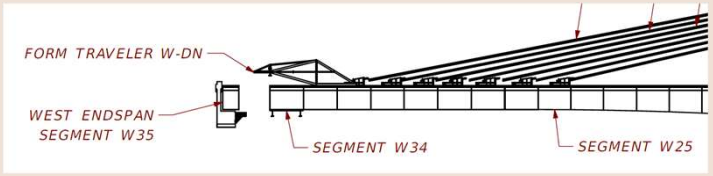
- Segment W32: 22 deg C
- Segment W34: **31 deg C!**
- Segment W35: 27 deg C

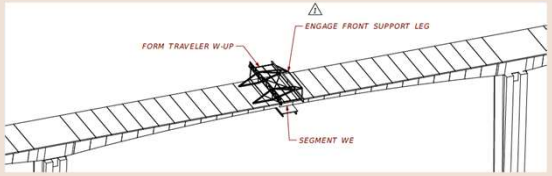
Geometry Control – Stay Construction





Geometry Control – Closures





Current Project Status

Lessons Learned

- External temporary PT system is a feasible means of extending the cantilever length, however, it is an expensive alternative.
- Develop a geometry control plan to incorporate thermal displacements to achieve correct geometry at closure.

Q&A

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