Best viewed on the PowerPoint desktop app

MIDAS Civil

Post Tensioned Balanced Cantilever Talk with AtkinsRéalis

21st October 2025

AtkinsRéalis

AGENDA

Henry Still

Engineer
AtkinsRéalis
Cardiff UK

Tender phase
Year in industry student

Swansea University
Prifysgol Abertawe

Design phase
Graduate engineer on PT Viaduct

Construction Phase
Structural lead engineer on PT Viaduct

AtkinsRéalis

Engineering a better future for our planet and its people

38k
People

50
Countries

1911
Founded

Road Project

Road Project


NEWS

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Wales | Wales Politics | Wales Business | North West | North East | Mid | South West | South East | Cymru

Works on 'road from hell' to end after 23 years

Key figures

All sections

23 years £1.3bn 45km

Last Section

40 bridges £500m 18km

Complex bridge in a complex location

- **Key junction between roads**
- **Live traffic to be maintained**
- **Adjacent to:**
  - National Park
  - Listed Bridge
  - Existing post tensioned bridge
  - Multiple houses

Proposed Solution

Post tensioned balanced cantilever

180m in length

75m maximum span

35m from the valley floor

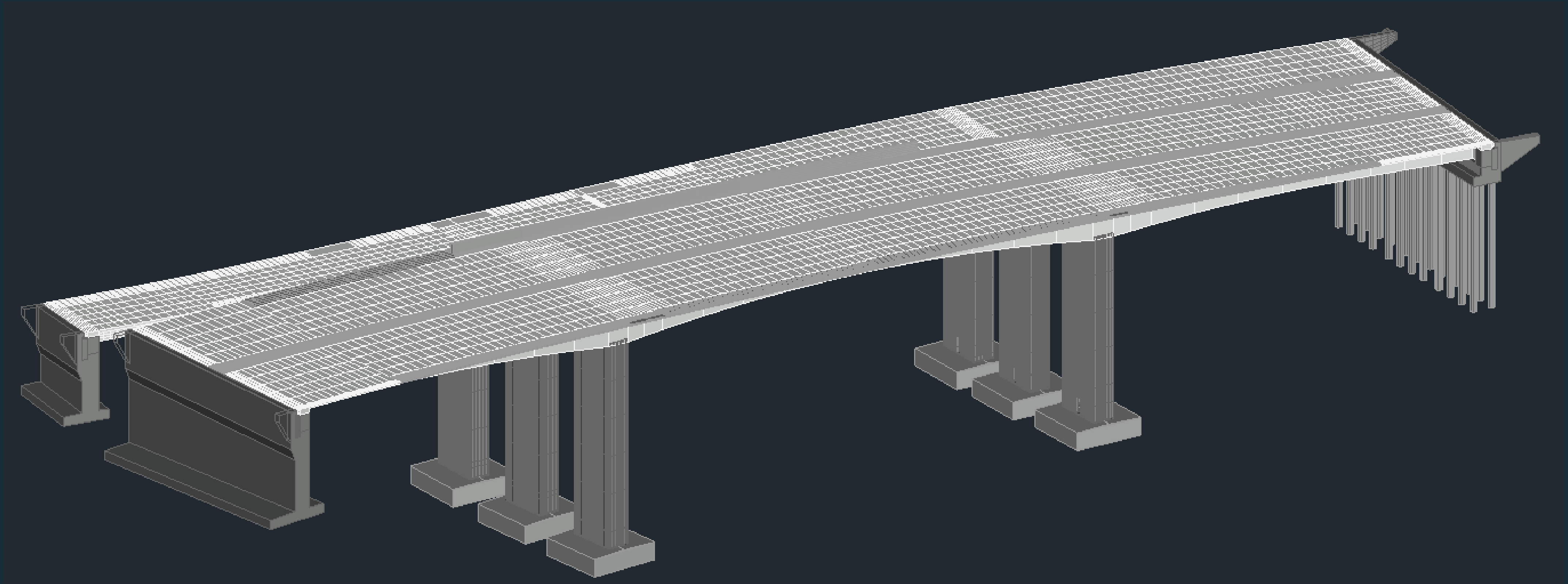
Odd things to note

Eastbound on slip joins at midspan

The strucutre has a significant curve

On slip changes cross and long fall

3 abutments, of which only 1 is piled



Post Tensioned Balanced Cantilevers

Method of construction

Segments are built out from the piers.

Can be precast or in-situ.

Post tensioning

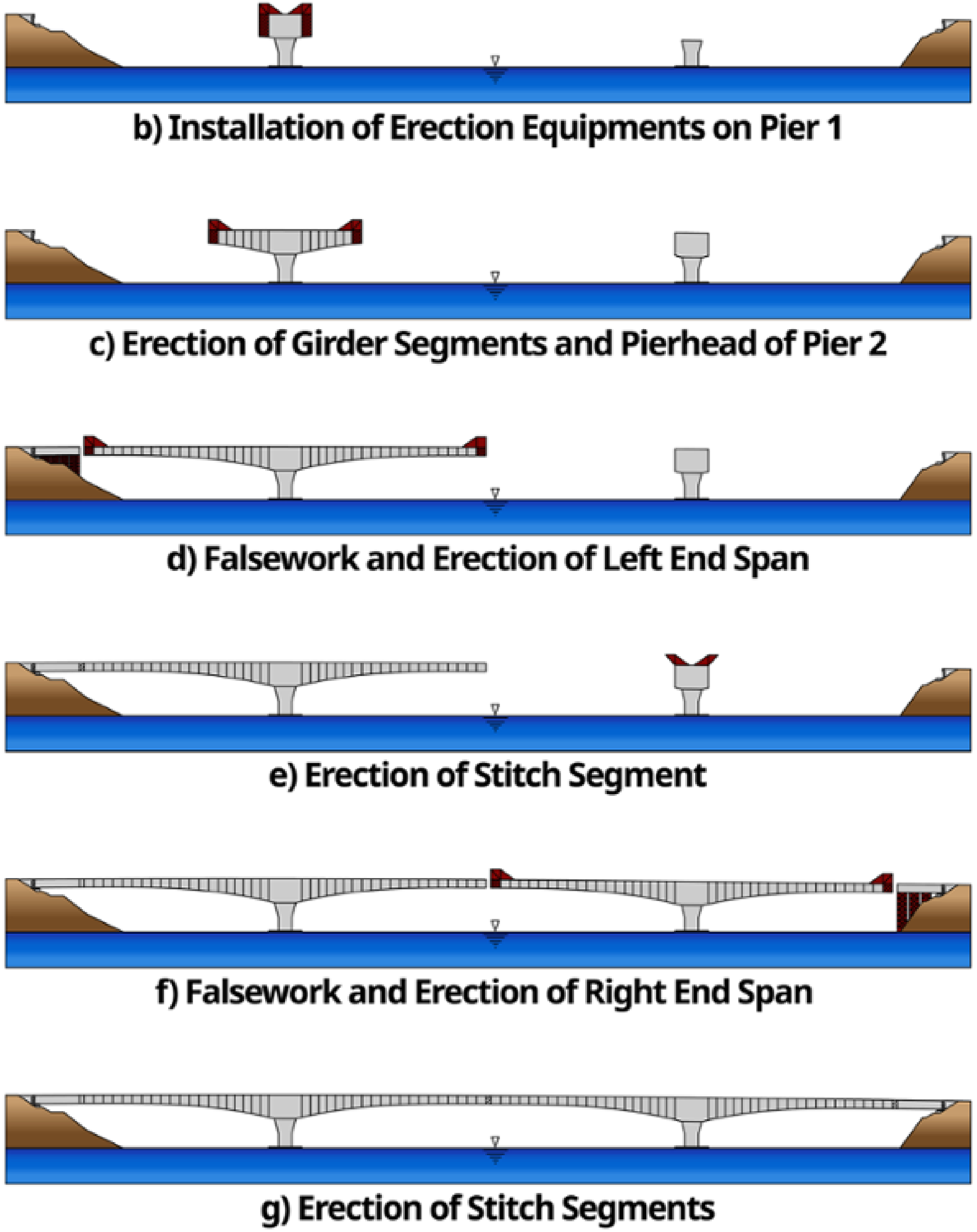
Tendons run through the segments

Stressing sequence is key to the structure's strength.

Construction Sequence

Typical Sequence

- Build pier
- Construct pierhead/ diaphragm
- Assemble moving formwork
- Assemble segments
- Cross fingers and hope they meet in the middle



Pros vs Cons

Positives

- Efficient for spans 70m - 300m
- Minimal formwork
- Good for difficult terrain
- Quick form of construction

Negatives

- Banned form of construction in the UK for 30 years
- Complex analysis
- Key structural elements are hidden

Time dependent effects

Key Time Dependent Effects

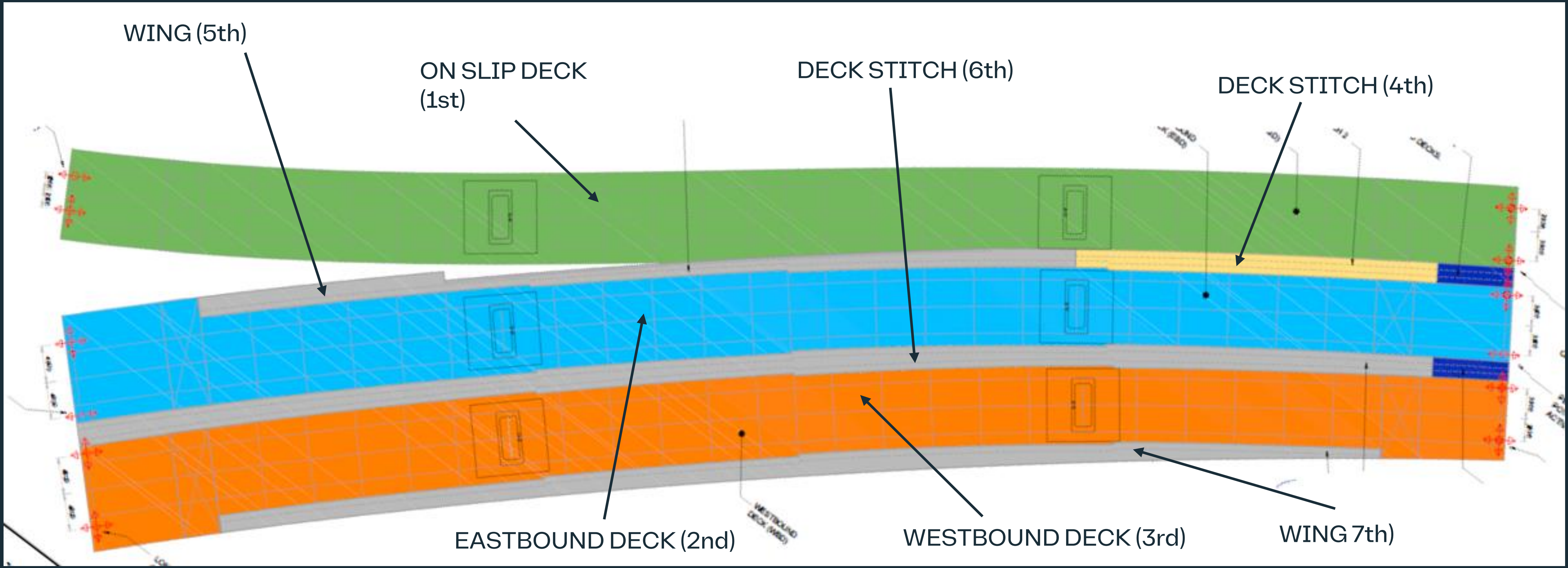
- Creep
- Shrinkage
- Tendon relaxations

Issues to be considered

- Each segment is a different age
- Tendons are all stressed at different times
- Deflections need to be managed

Very Sensitive to Construction Sequence

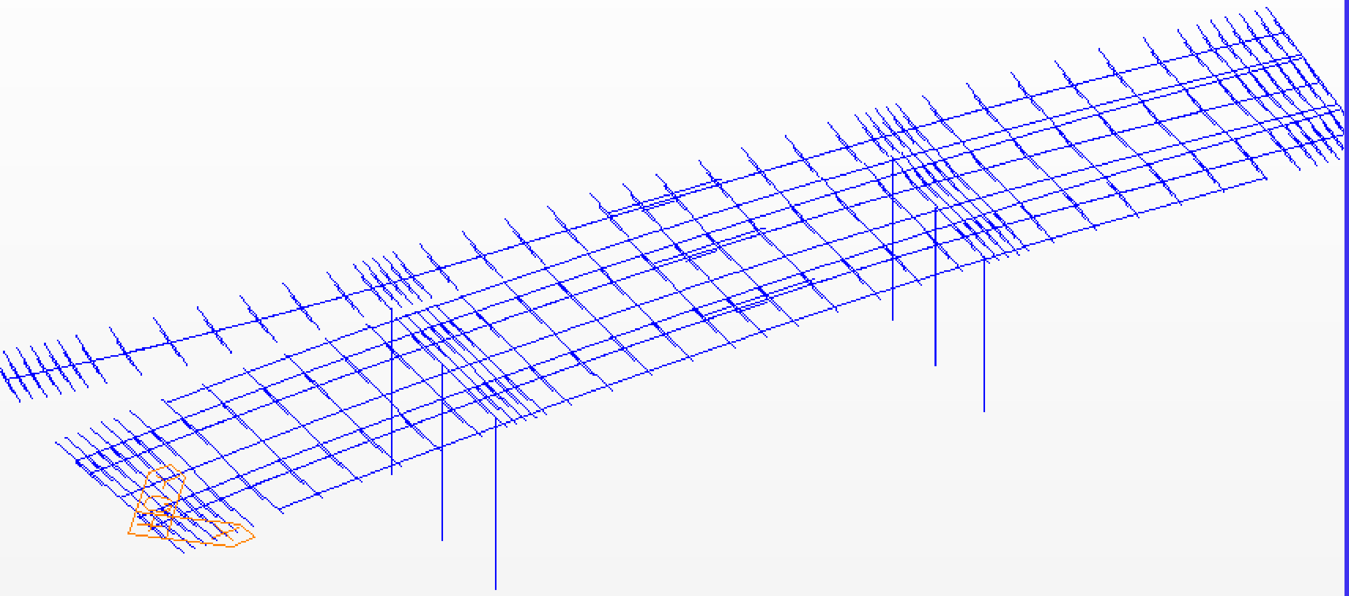
Proposed Sequence - Global



Modelling Software
Midas Civil

- **Construction Stages**
- **Time dependent materials**
- **Easily model and refine Tendons**

Modelling Strategy
Primary model



3 adjacent line beams

3 adjacent post tensioned viaducts get constructed

Tendons to be modelled

Grillage

The viaducts get stitched together to form the road junction. This requires the model to become a grillage.

Time

Critical case is not always the final phase. Model needs to consider time.

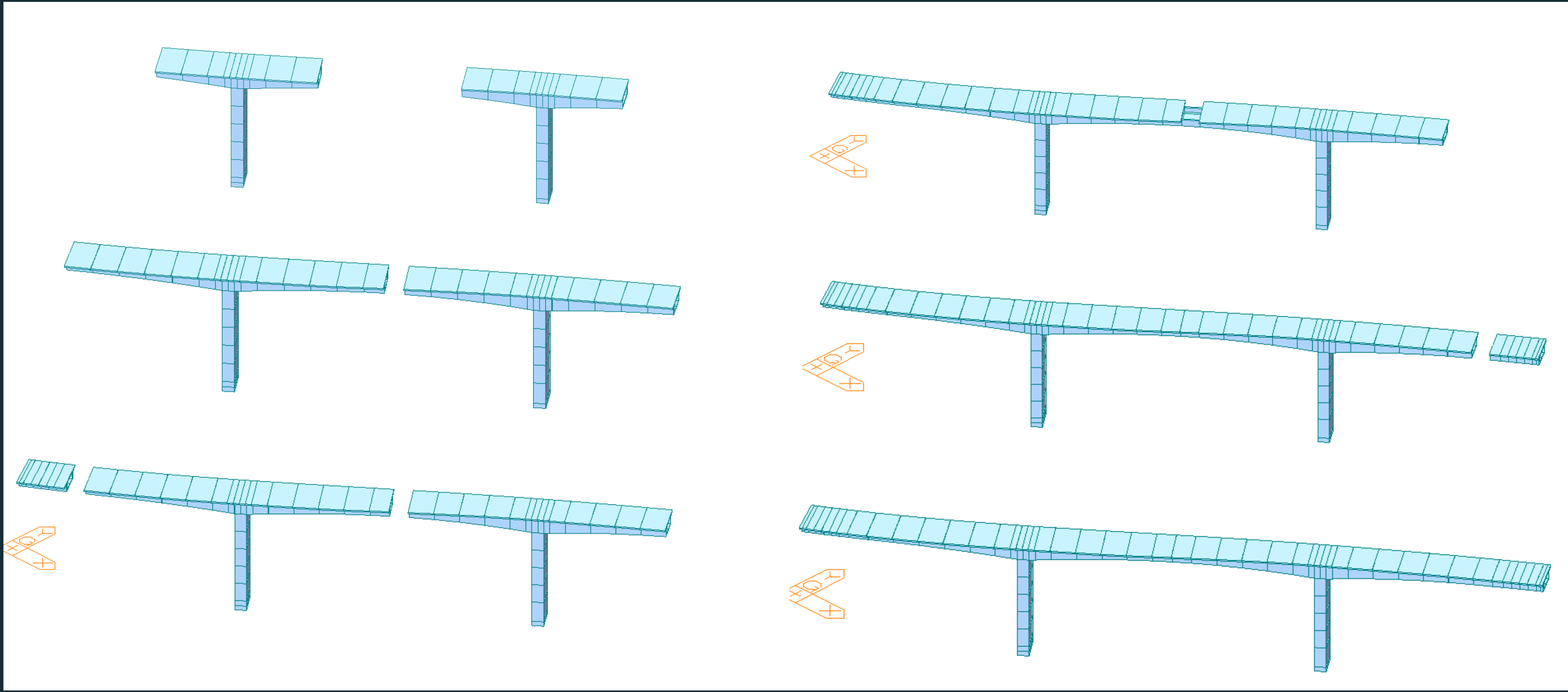
2057

Nodes

2218

Elements

Proposed Sequence - Viaduct



Formwork

Form travelers

4 custom made form travelers from Spain

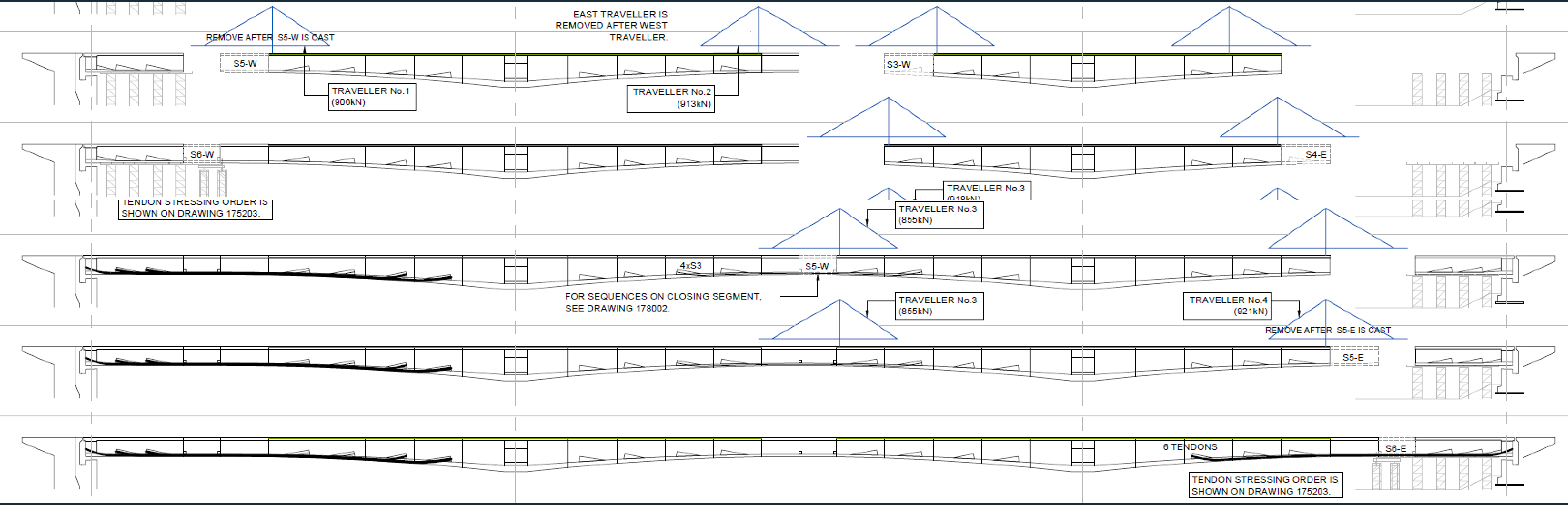
Weighing approximately 90 tons each.

Self lifting and launching.

Scaffolding

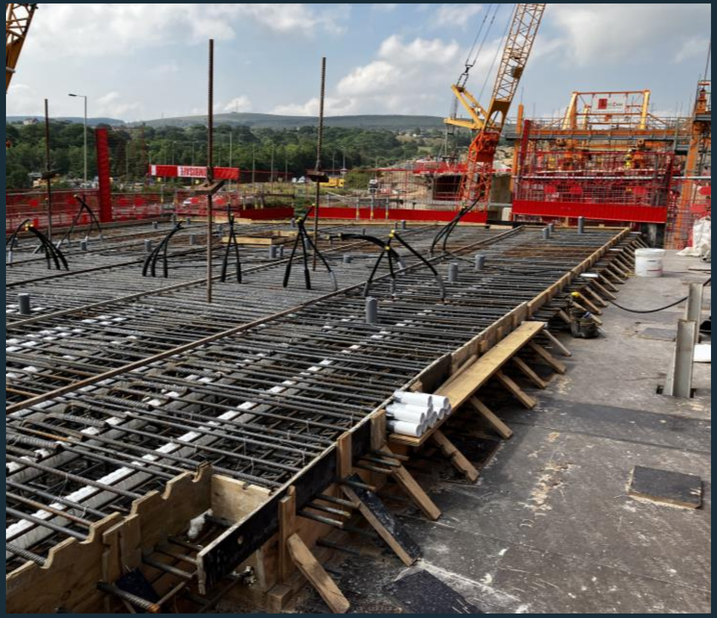
The final back span segments were cast on scaffolding

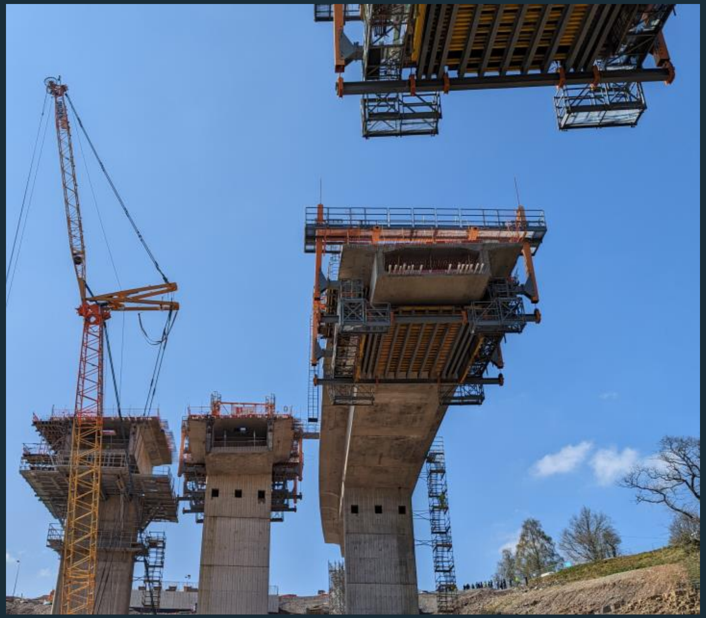
Closing segment sequence

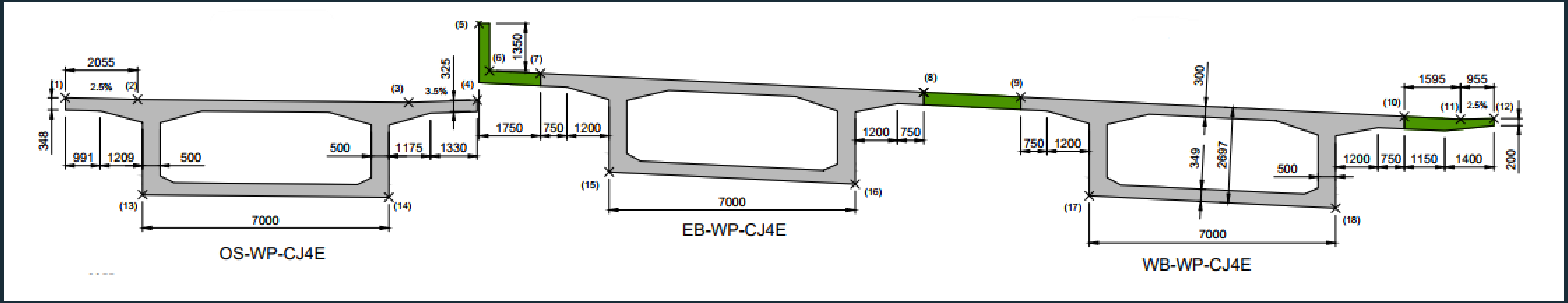


Deck Segments

- **Cast In-situ**
- **72 segments typically 6.4m long**
- **Tensioning in top slab, top of webs and bottom slab**

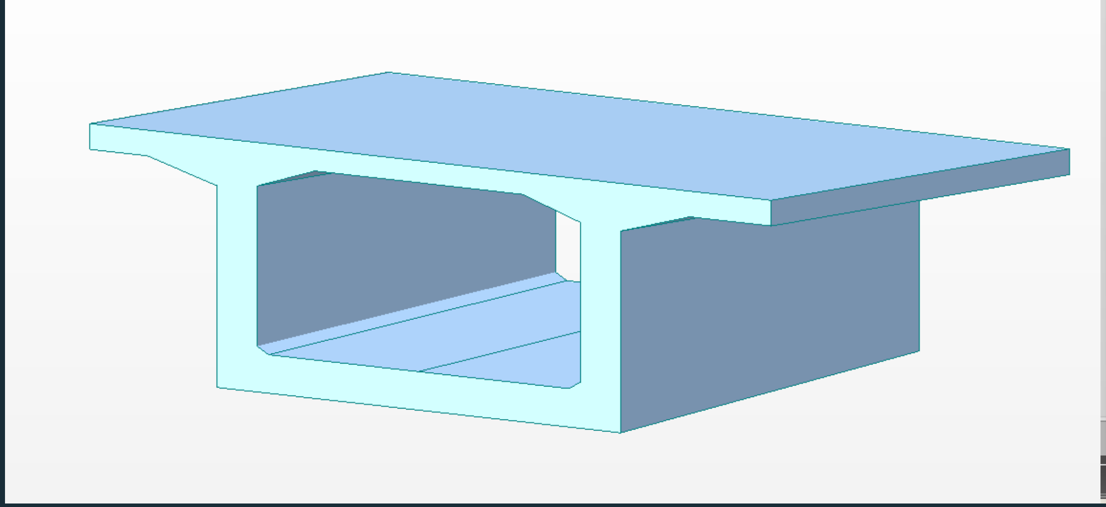


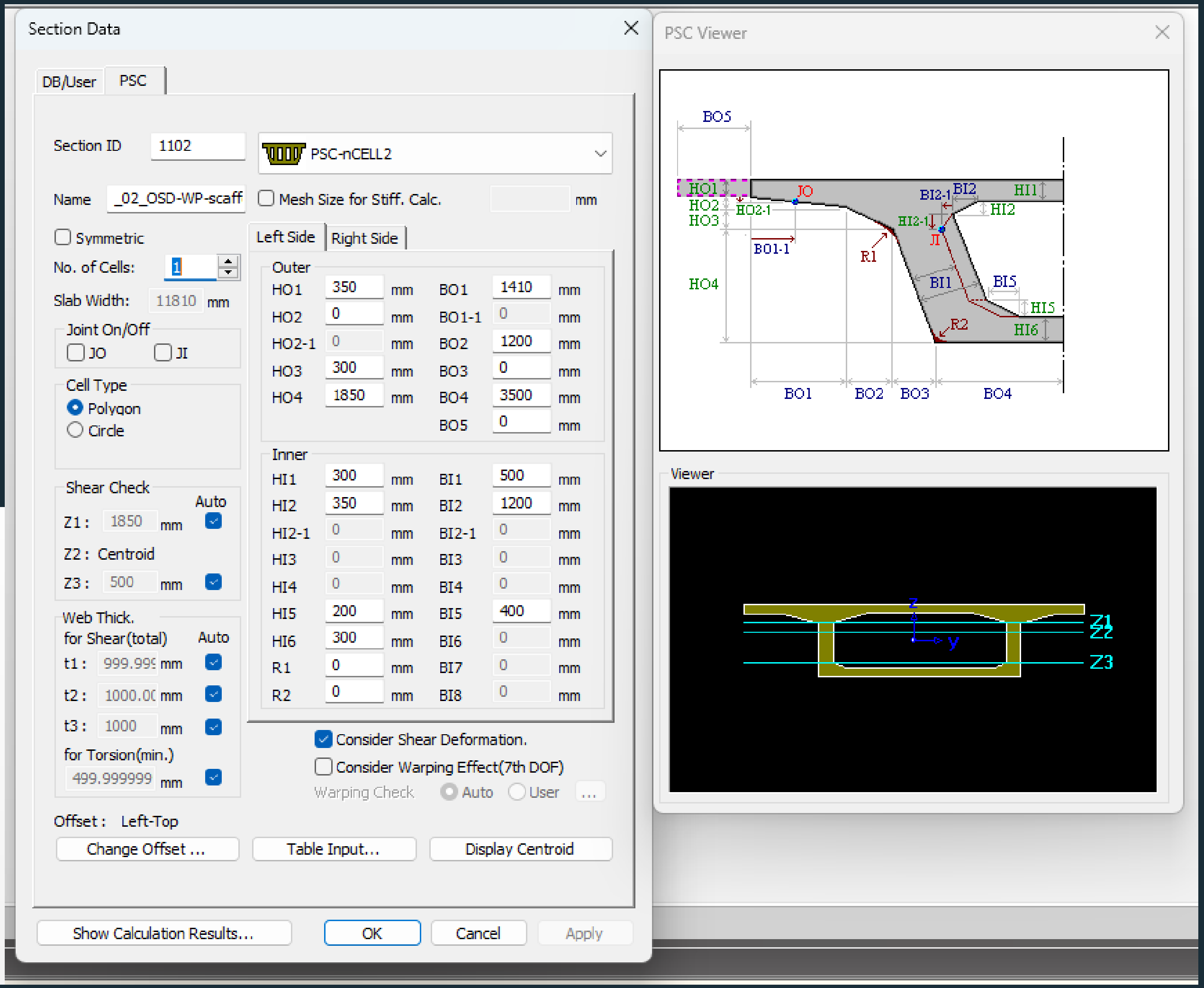




Deck Segments

Segments were created directly in MIDAS civil using PSC segments

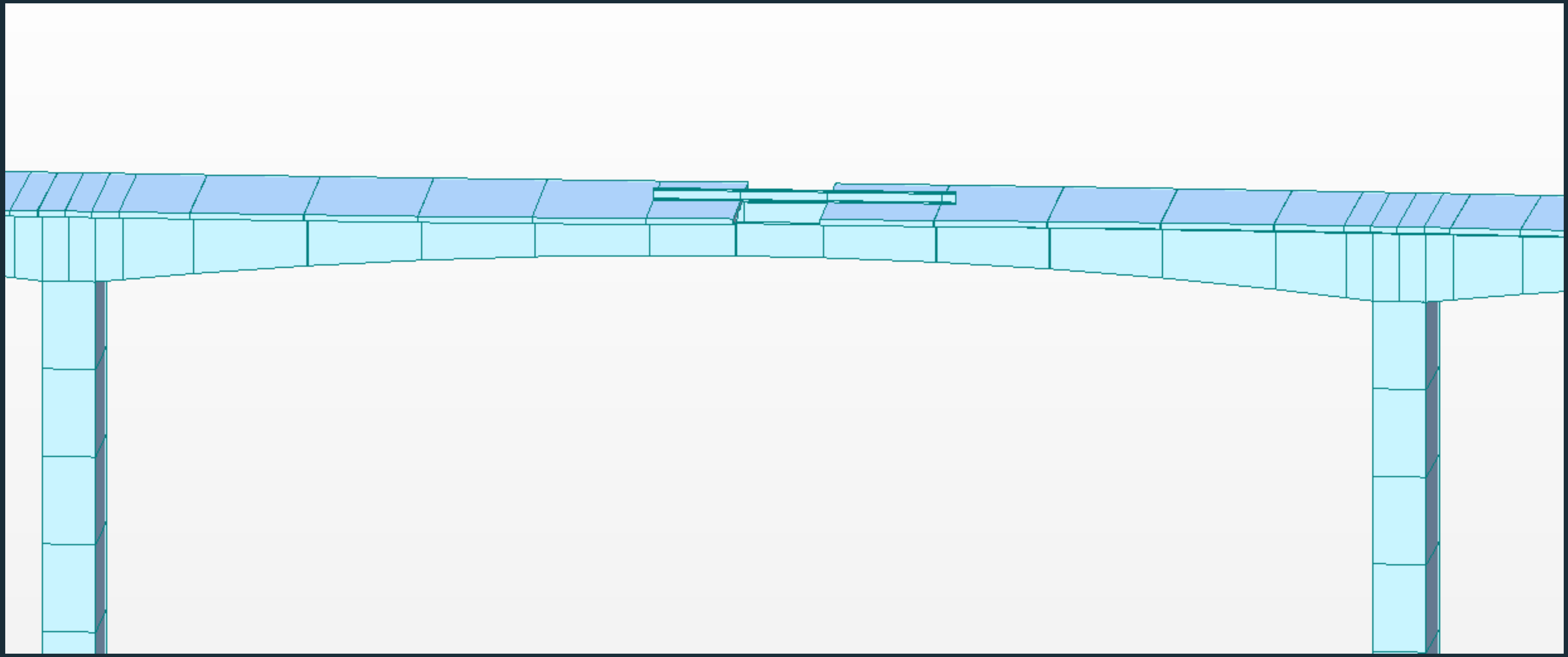




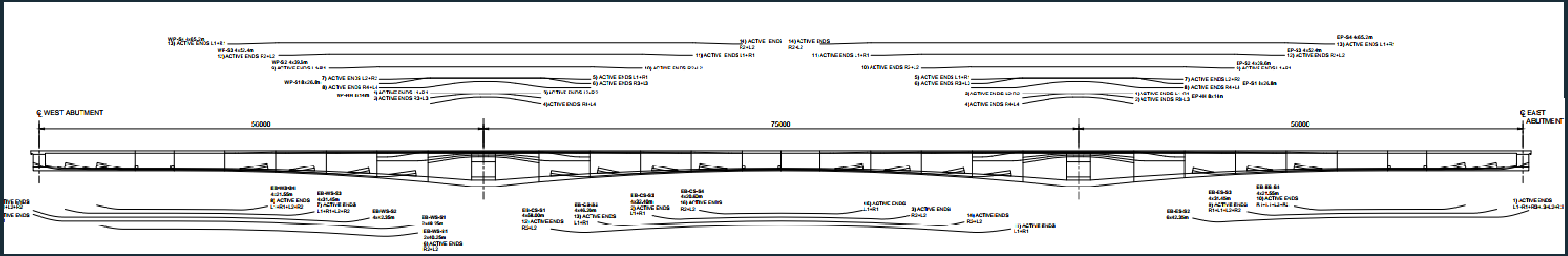
Closing Segments

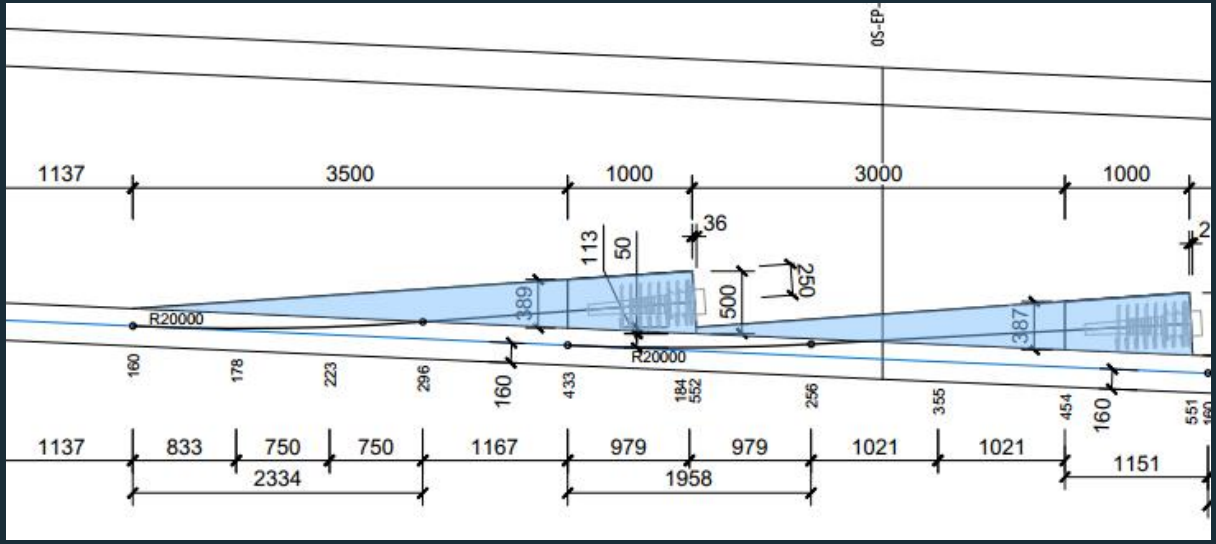
The final segments at midspan and backspan are not possible to be cast in a singular pour.

Model accounts for this by having a 2-stage composite element created in the section property calculator.

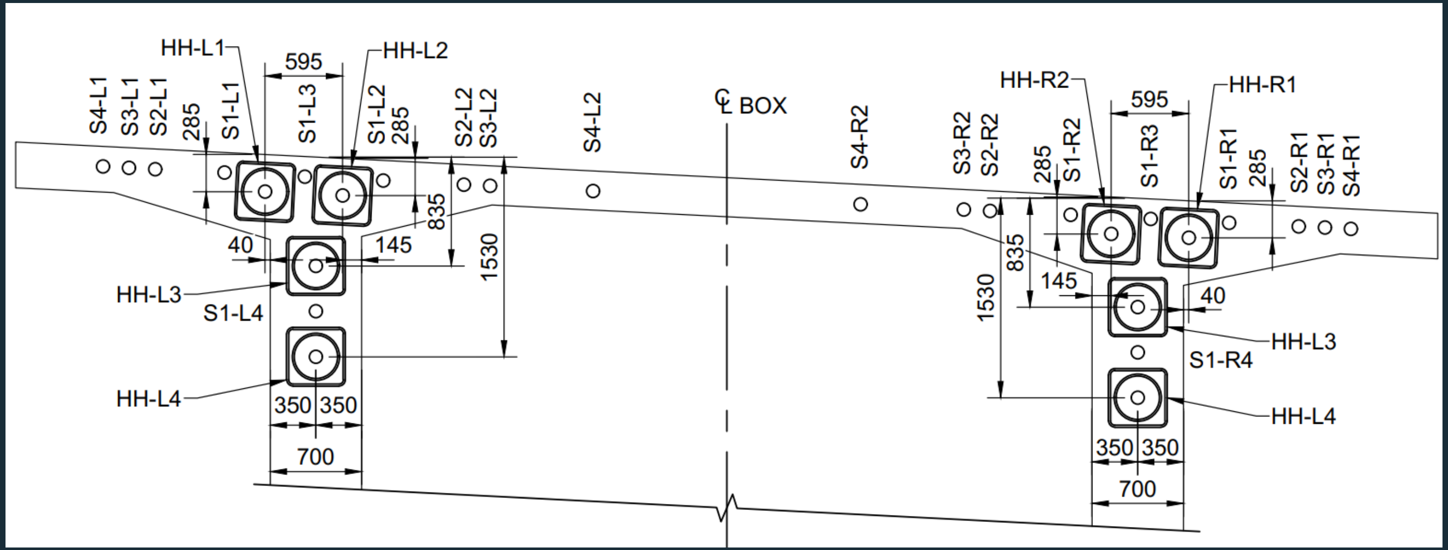


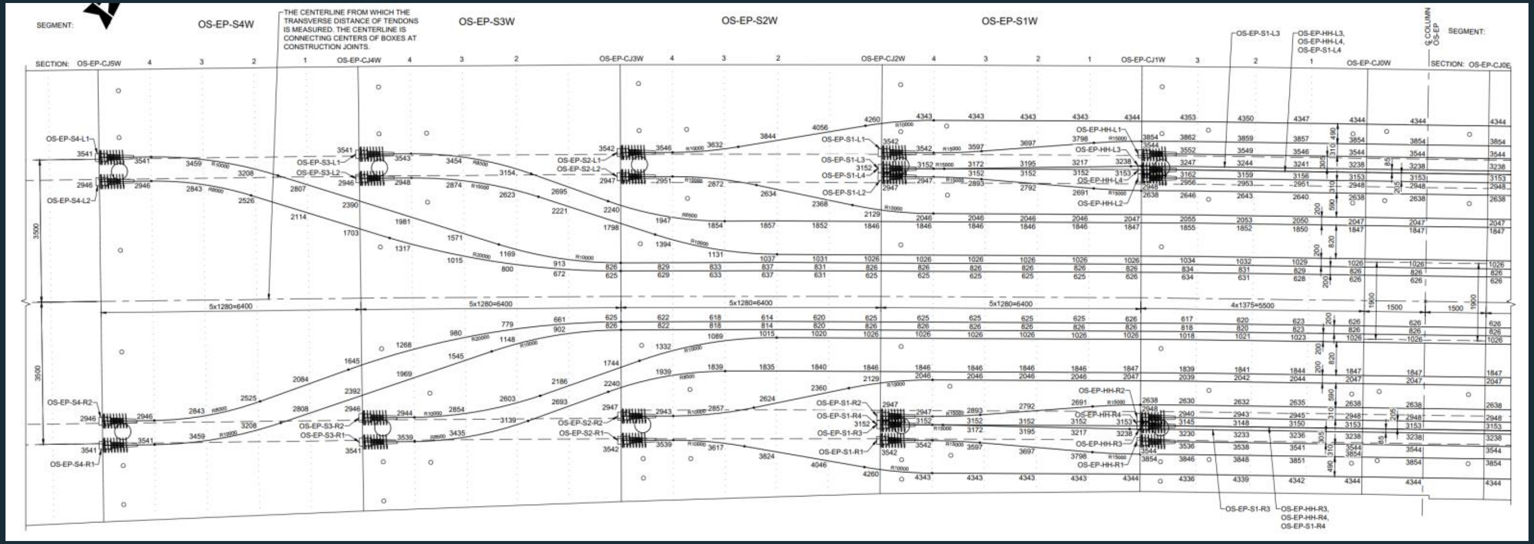
Post Tensioning





Post Tensioning





Tendons in MIDAS

Tendon properties

Automatically calculated relaxation coefficient.

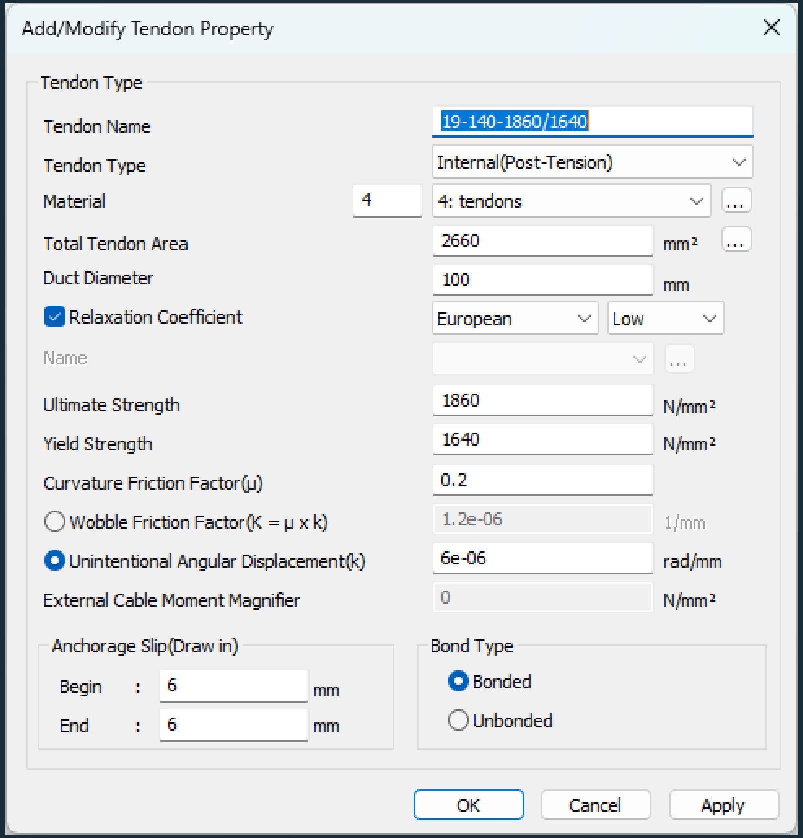
Easy to input other properties

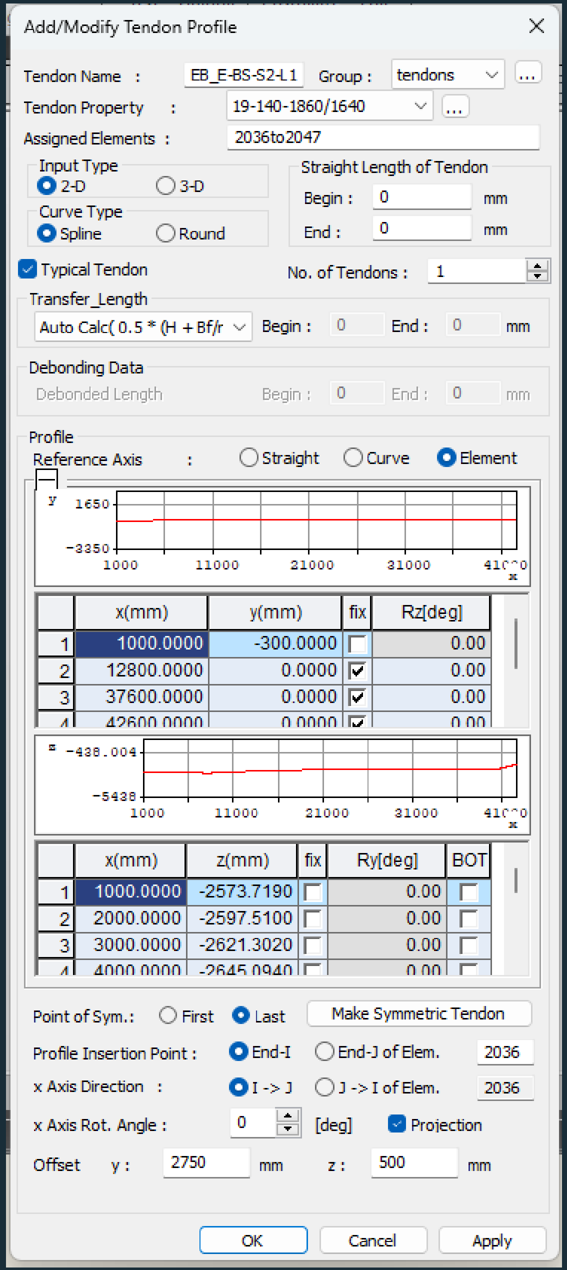
Tendon profiles

Profiles were first drafted in autoCAD and converted to excel tables

Tables were pasted into the profile tool.

Due to the lack of continuous tendons, the model has 308 tendon profiles.





Stressing sequence

Each tendon has a stressing order.

Top slab anchors get cast into the webs at the next deck segment pour

Curve effects must be managed.

	Tendon reference	Length [mm]	Stress applied [MPa]	Elongation [mm]	Stressing end [West / East]	Stressing order
CANTILEVER TENDONS - WESTBOUND DECK - WEST PIER	WB-WP-HH-L3	14245	1476	104	W	E
	WB-WP-HH-L3	14102	1476	104	E	E
	WB-WP-HH-L3	14211	1476	105	W	4
	WB-WP-HH-L4	14253	1476	104	E	6
	WB-WP-HH-R3	14125	1476	104	W	E
	WB-WP-HH-R2	14133	1476	104	E	6
	WB-WP-HH-R3	14131	1476	104	W	E
	WB-WP-HH-R4	14171	1476	105	E	7
	WB-WP-S3-L1	27070	1476	191	E	9
	WB-WP-S4-L2	27049	1476	191	W	18
	WB-WP-S4-L2	27195	1476	185	E	15
	WB-WP-S1-L4	27117	1476	191	W	26
	WB-WP-S3-R1	26910	1476	191	E	10
	WB-WP-S4-R2	26941	1476	191	W	18
	WB-WP-S4-R2	26918	1476	185	E	15
	WB-WP-S4-R1	26991	1476	193	W	19
	WB-WP-S3-L1	40038	1476	273	W	27
	WB-WP-S2-L2	39987	1476	268	E	20
	WB-WP-S3-R1	39775	1476	269	W	18
	WB-WP-S4-R2	39845	1476	269	E	18
	WB-WP-S3-L1	52939	1476	351	E	27
	WB-WP-S4-L2	52861	1476	351	W	26
	WB-WP-S3-R1	52536	1476	351	E	27
	WB-WP-S4-R2	52654	1476	351	W	27
	WB-WP-S4-L2	65874	1476	432	W	27
	WB-WP-S4-L2	65871	1476	421	E	26
	WB-WP-S4-R1	65358	1476	429	W	24
	WB-WP-S4-R2	65711	1476	421	E	27
CANTILEVER TENDONS - WESTBOUND DECK - EAST PIER	WB-EP-HH-L3	14253	1476	104	E	E
	WB-EP-HH-L3	14139	1476	104	W	E
	WB-EP-HH-L3	14245	1476	105	E	4
	WB-EP-HH-L4	14288	1476	104	W	6
	WB-EP-HH-R3	14087	1476	104	E	E
	WB-EP-HH-R3	14102	1476	104	W	6
	WB-EP-HH-R3	14098	1476	104	E	E
	WB-EP-HH-R4	14139	1476	105	W	7
	WB-EP-S3-L2	27163	1476	193	W	9
	WB-EP-S4-L2	27117	1476	191	E	18
	WB-EP-S3-L2	27205	1476	187	W	12
	WB-EP-S1-L4	27195	1476	191	E	26
	WB-EP-S3-R2	26827	1476	190	W	10
	WB-EP-S4-R2	26873	1476	191	E	18
	WB-EP-S4-R2	26918	1476	185	W	15
	WB-EP-S1-R4	26913	1476	190	E	15
	WB-EP-S4-L2	40064	1476	273	E	27
	WB-EP-S4-L2	40064	1476	270	W	20
	WB-EP-S4-R2	39620	1476	269	E	18
	WB-EP-S2-R2	39767	1476	268	W	19
	WB-EP-S4-L2	53175	1476	341	W	27
	WB-EP-S3-L2	53184	1476	337	E	24
	WB-EP-S4-R2	52856	1476	339	W	27
	WB-EP-S3-R2	52996	1476	336	E	23
	WB-EP-S4-L2	66244	1476	419	E	27
	WB-EP-S4-L2	66041	1476	420	W	26
	WB-EP-S4-R2	66015	1476	419	E	26
	WB-EP-S4-R2	65874	1476	419	W	27

	Tendon reference	Length [mm]	Stress applied [MPa]	Elongation [mm]	Stressing end [West / East]	Stressing order
CONTINUITY TENDONS - WESTBOUND DECK - WEST SPAN	WB-WS-S4-L1	43524	1476	301	E	18
	WB-WS-S4-L1	39479	1476	286	E	18
	WB-WS-S3-R2	43326	1476	300	E	27
	WB-WS-S3-R2	39366	1476	286	E	26
	WB-WS-S2-L3	41461	1476	187	W	12
	WB-WS-S4-L1	41430	1476	396	W	6*
	WB-WS-S2-L3	41415	1476	290	W	41
	WB-WS-S3-R2	41298	1476	286	W	27
	WB-WS-S3-R2	41316	1476	286	W	6*
	WB-WS-S3-R2	41331	1476	286	W	33
	WB-WS-S4-L1	30684	1476	286	E	27
	WB-WS-S4-L1	30661	1476	286	E	27
	WB-WS-S3-R2	30574	1476	212	E	27
	WB-WS-S3-R2	30598	1476	212	E	26
	WB-WS-S4-L1	20775	1476	148	E	26
	WB-WS-S4-R1	20698	1476	148	E	25
CONTINUITY TENDONS - WESTBOUND DECK - CENTRAL SPAN	WB-CS-S1-L1	58458	1476	395	E	31
	WB-CS-S4-L2	58380	1476	318	W	33
	WB-CS-S4-L2	58043	1476	318	E	18
	WB-CS-S1-R1	58043	1476	396	E	26
	WB-CS-S4-R2	58092	1476	396	W	40
	WB-CS-S4-R2	58129	1476	396	E	27
	WB-CS-S2-L1	46559	1476	318	W	47
	WB-CS-S4-L2	46485	1476	318	E	46
	WB-CS-S4-L2	46454	1476	212	W	49
	WB-CS-S2-R3	46261	1476	316	W	41
	WB-CS-S4-R2	46335	1476	212	E	49
	WB-CS-S2-R3	46366	1476	317	W	44
	WB-CS-S4-L2	32750	1476	229	W	7 *
	WB-CS-S4-L2	32701	1476	229	E	10 *
	WB-CS-S4-R2	32570	1476	278	W	9 *
	WB-CS-S4-R2	32619	1476	278	E	9 *
	WB-CS-S4-L2	20931	1476	150	E	47
	WB-CS-S4-L2	20865	1476	145	W	50
	WB-CS-S4-R2	20786	1476	145	E	49
	WB-CS-S4-R2	20805	1476	145	W	49
CONTINUITY TENDONS - WESTBOUND DECK - EAST SPAN	WB-ES-S2-L1	40971	1476	286	E	13*
	WB-ES-S4-L1	40940	1476	187	E	15*
	WB-ES-S4-L2	40834	1476	286	E	16*
	WB-ES-S2-R1	40794	1476	285	E	12*
	WB-ES-S4-R2	40817	1476	286	E	16*
	WB-ES-S4-R2	40834	1476	286	E	13*
	WB-ES-S4-L2	30153	1476	212	W	26
	WB-ES-S4-L2	30142	1476	212	W	29
	WB-ES-S4-R2	30061	1476	212	W	27
	WB-ES-S4-R2	30072	1476	212	W	34
	WB-ES-S4-L1	20268	1476	145	W	31
	WB-ES-S4-L2	20237	1476	145	W	33
	WB-ES-S4-R1	20159	1476	145	W	31
	WB-ES-S4-R2	20188	1476	145	W	34

Lengths of tendons are determined from end of anchor heads.
All tendons are stressed only from one side.

x * Tendons which are stressed after closing segment in particular span is cast.

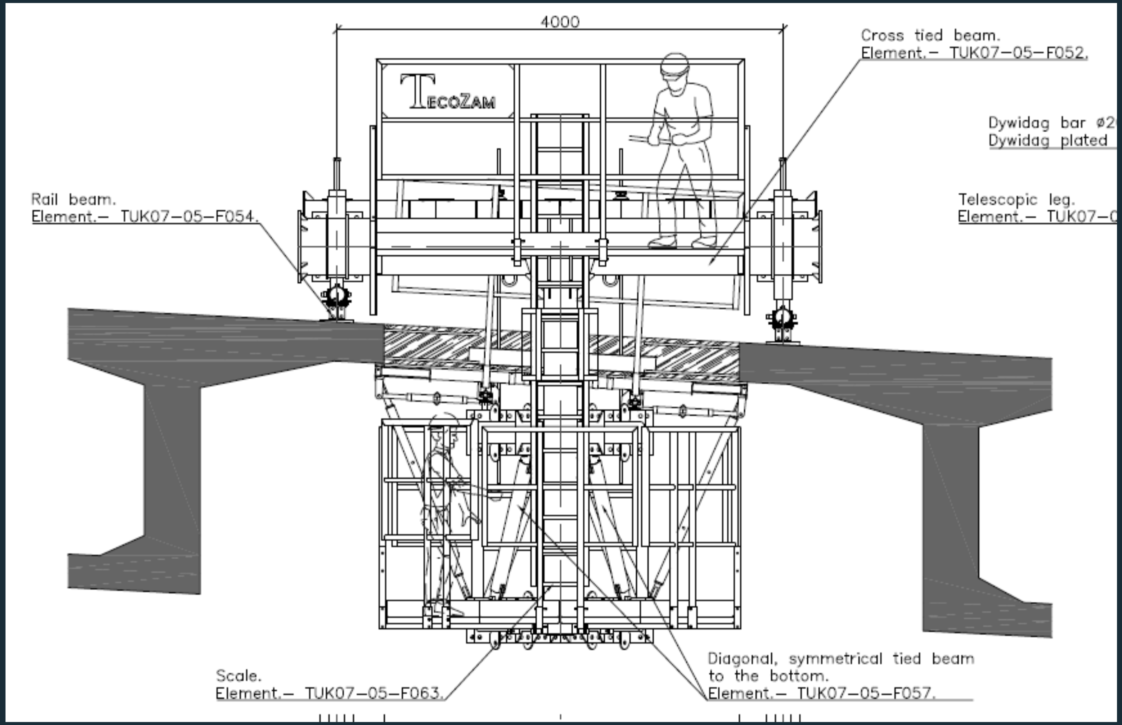
Deck stiches

Connecting the viaducts

Due to the merging onslip the 3 viaducts need to be attached.

A stitch traveler was used.

Due to only having 4 main form travelers each viaduct is completed at a different time. So, the decks are different ages when connected and are undergoing different stages of deflection.



How many construction stages in the model do you have?

108

Construction Stages

Element

Each deck segment is represented as an element.

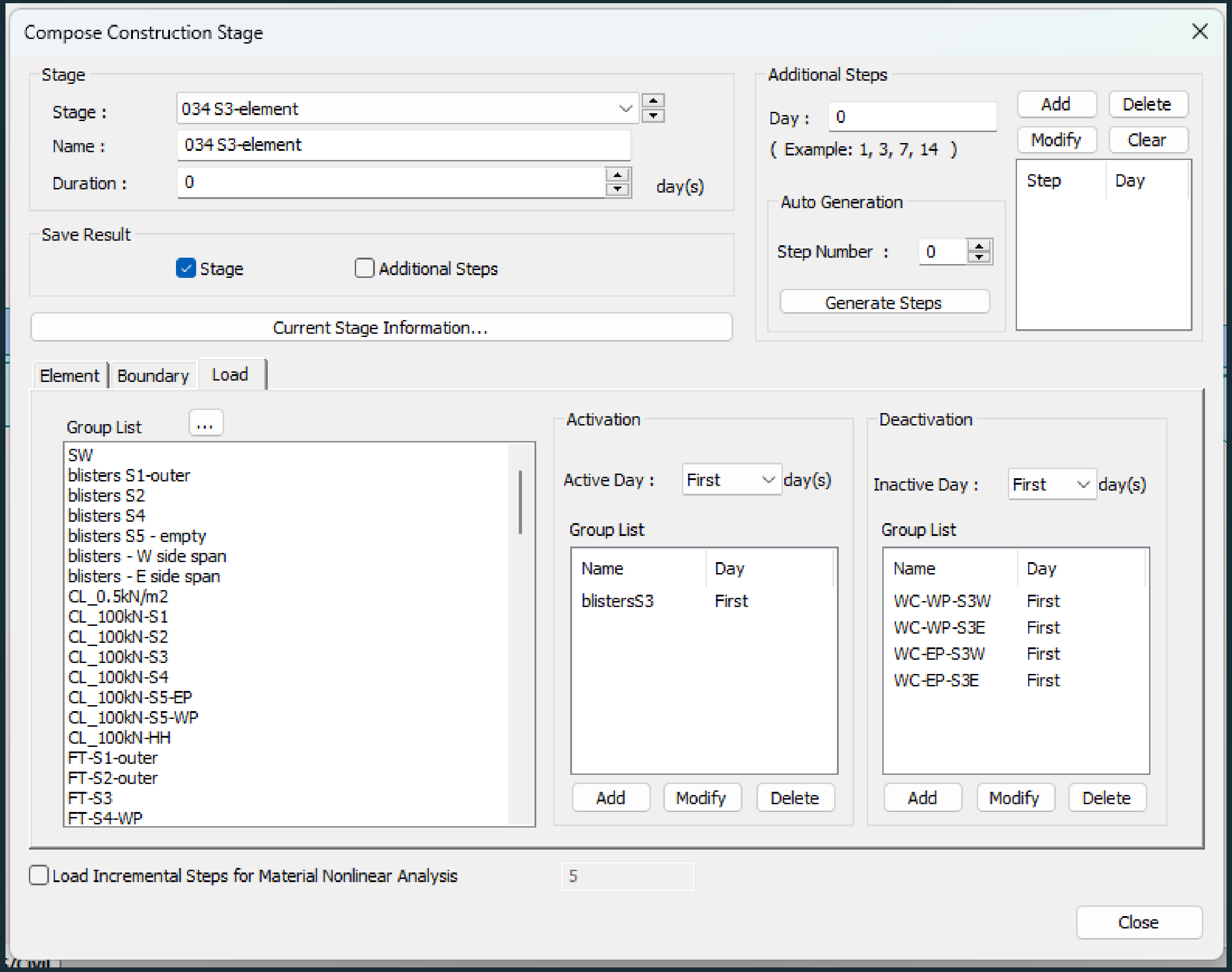
Boundary

Each viaduct needed a transverse fixed bearing, in the final state only 1 is transversely fixed per abutment.

Load

Various load groups are activated and deactivated.

Such as representing the form traveler moving.



Do NOT change the Construction Sequence

Moving loads

Code

The bridge was to be designed to Eurocode with UK National Annex

Lanes

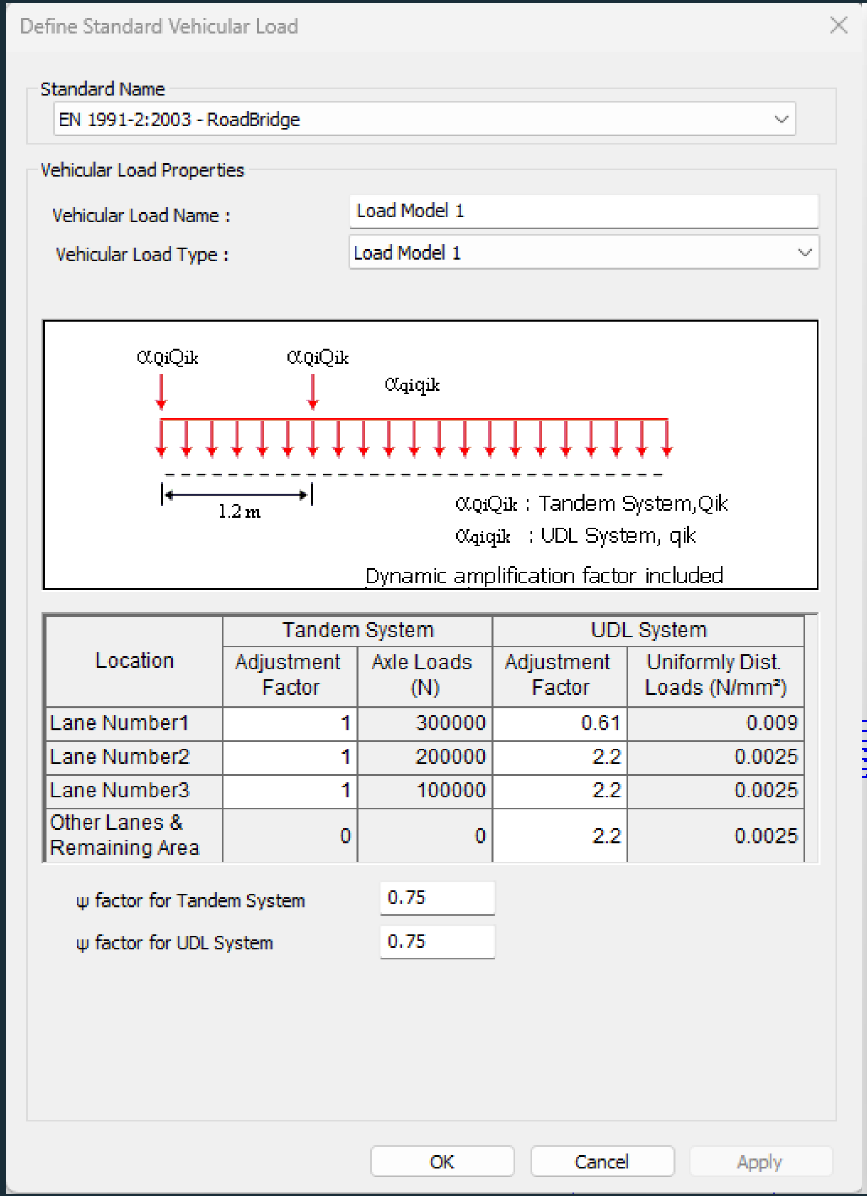
Due to a grillage model being used traffic line lanes were defined. Due to the geometry there were 19 different lanes to check.

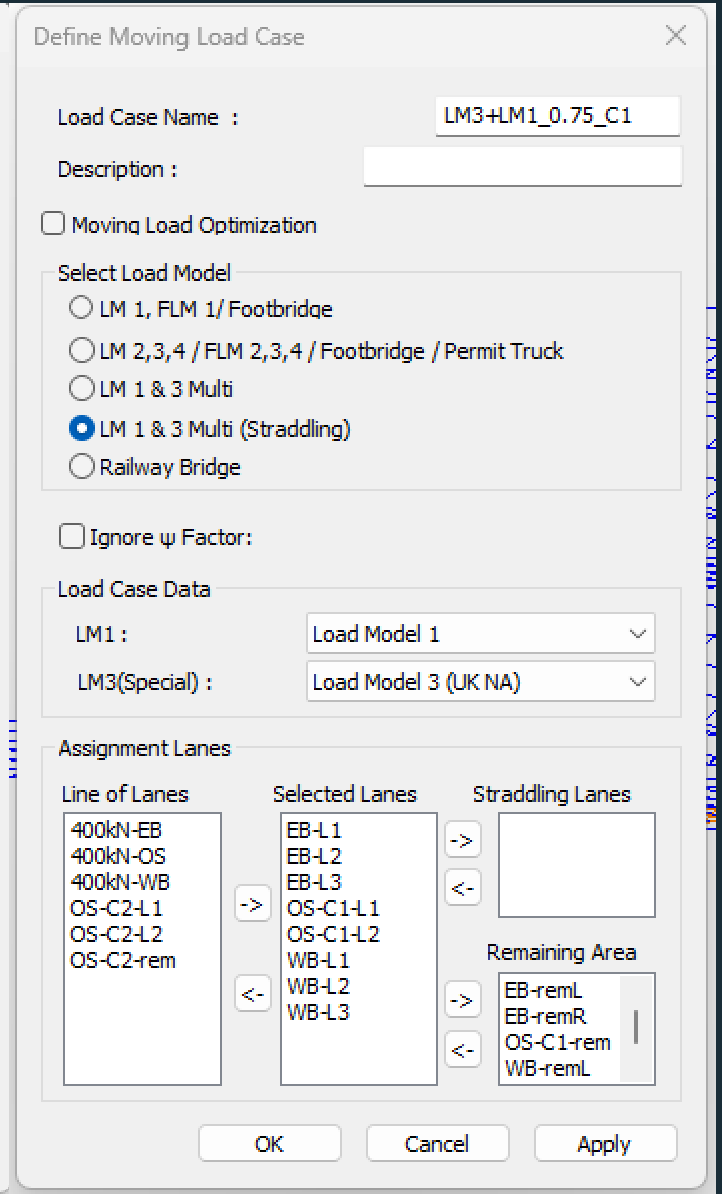
Vehicles

Standard vehicles and a project specific custom vehicle were created.

Moving load cases

The inbuilt midas moving load combination tool was used to quickly assemble the multiple load cases.





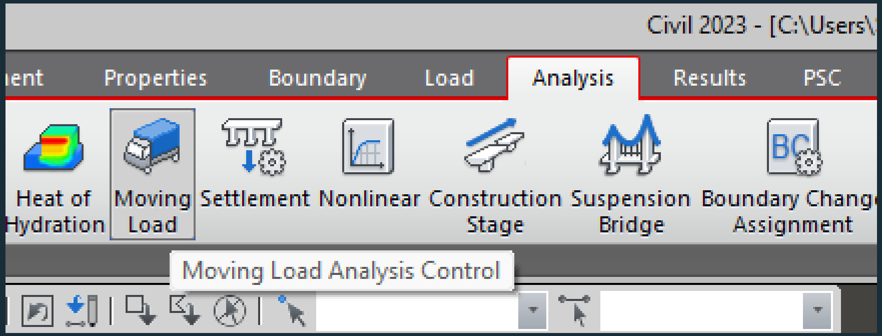
Speeding up analysis

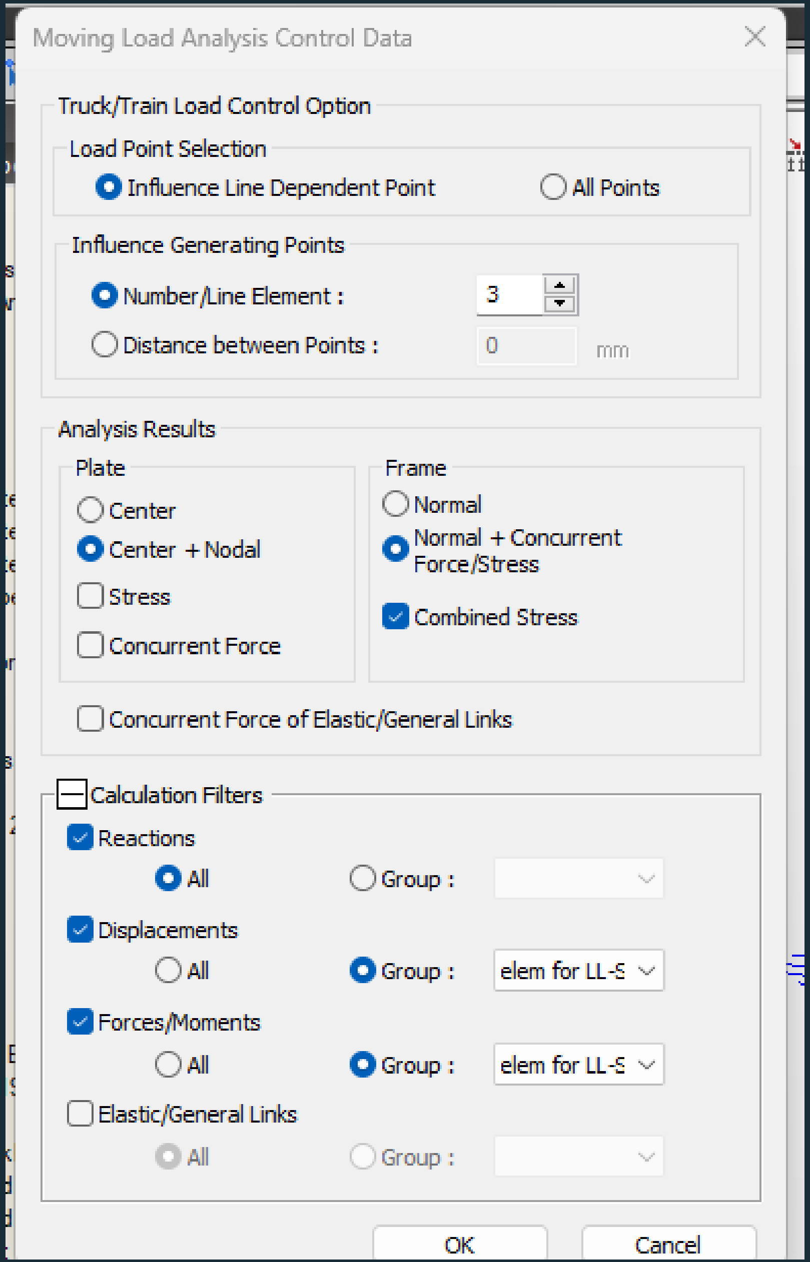
Without filters

Without the model will check all elements for all positions. This is inefficient causing the model to take 9 hours to run.

With filters

These groups reduce the amount of load positions to check and reduced the model run time down to approximately 2 hours.



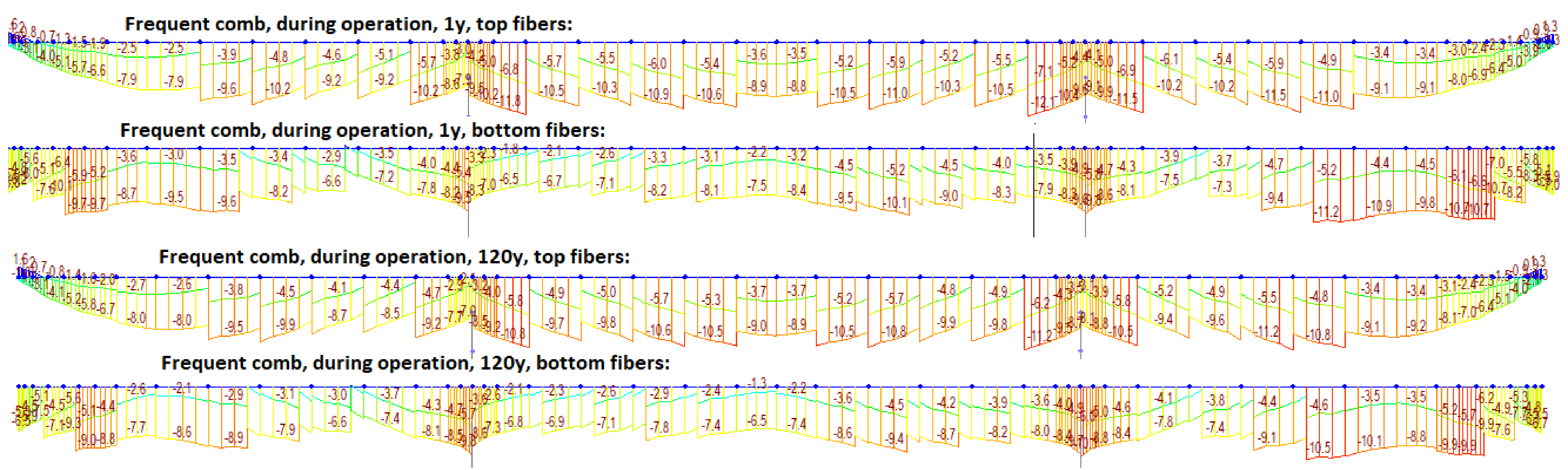


Stress results

MIDAS Stress results

The result graphs in Midas enabled quick analysis of the element stress at the extreme fibers. A key requirement of post tensioning requires the element to be in compression under the frequent case.

A diagram allowed for quick alteration to the tendon design.



Other results

Result tables

Other results were obtained through the result tables and inspecting diagrams.

These were then extracted to excel where capacities were checked.

Moment-y	primary component		OSD-WP-S7W-07-W		OSD-WP-S7W-07-E		OSD-WP-S6W-W		OSD-WP-S6W-E		OSD-WP-S5W-W		OSD-WP-S5W-E		OSD-WP-S4W-W		OSD-WP-S4W-E		OSD-WP-S3W-W		OSD-WP-S3W-E		OSD-WP-
		Key Inputs	SAG	HOG	SAG	HOG	SAG	HOG	SAG	HOG	SAG	HOG	SAG	HOG	SAG	HOG	SAG	HOG	SAG	HOG	SAG	HOG	SAG
	bending		54	-	53	-	54	-	54	-	53	-	52	-	53	-	60	-	60	-	47	51	50
	Links in webs	Shear Web	78	-	98	-	95	-	84	-	41	-	51	-	72	-	70	-	58	-	47	61	58
	Transverse in top slab	Trans top slab	57	-	61	-	56	-	57	-	46	-	49	-	49	-	50	-	46	-	49	46	46
	longitudinal bars in webs	long web	49	-	52	-	47	-	47	-	36	-	37	-	37	-	36	-	33	-	33	30	30
	lonitudinal bars in top slab	long top slab	31	-	32	-	20	-	24	-	1	-	7	-	12	-	8	-	2	-	7	1	0
	lonituidnal bars in bottom slab	long bottom slab	31	-	32	-	20	-	24	-	1	-	7	-	12	-	8	-	2	-	7	1	0
	shear compression strut	shear strut	30	-	36	-	24	-	18	-	1	-	7	-	22	-	17	-	28	-	21	33	22
	torsion compression strut	torsion strut	35	-	41	-	27	-	22	-	1	-	8	-	24	-	19	-	28	-	22	33	22
		Loading																					
kNm	Design Applied Moment	M_{Ed} =	81475	NO HOG	94436	NO HOG	94465	NO HOG	107888	NO HOG	107950	NO HOG	106206	NO HOG	106167	NO HOG	85183	NO HOG	85168	NO HOG	50381	42076	50338
kNm	Design Applied Torque	T_{Ed} =	5785		6873		4349		5095		-199		1528		-2060		-1929		-394		-1817	169	-38
kN	Design applied Shear - full box	V_{Ed} =	-4923		-4841		-3195		-2279		-134		894		3409		2843		5326		5361	8035	7777
kN	Secondary Shear force from induced reactions from prestressing force	$V_{P,secondary,Ed}$ =	0		0		0		0		0		0		0		0		0		0	0	0
	% redistribution of Web 1	Web 1 =	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4
	% redistribution of Web 2 * adopted for checks as most onerous	Web 2 =	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6
		Geometry																					
mm	Full Box depth	D =	2500	2500	2500	2500	2500	2500	2500	2500	2500	2500	2537	2537	2537	2537	2697	2697	2697	2697	2983	2983	2983
mm	Top Slab depth	d_u =	300	300	300	300	300	300	300	300	300	300	300	300	300	300	300	300	300	300	300	300	300
mm	Top Slab Width	b_u =	11810	11810	11810	11810	11810	11810	11810	11810	11810	11810	11810	11810	11810	11810	11810	11810	11810	11810	11810	11810	11810
mm	Width of web at interface, if different to $b_{w,eq}$	$b_{w,int}$ =	2900	2900	2900	2900	2900	2900	2900	2900	2900	2900	2900	2900	2900	2900	2900	2900	2900	2900	2900	2900	2900
mm	Haunch Depth	d_{haunch} =	650	650	650	650	650	650	650	650	650	650	650	650	650	650	650	650	650	650	650	650	650
mm	Depth to centroid of deck slab with haunches	$d_{u,eff}$ =	183	183	183	183	183	183	183	183	183	183	183	183	183	183	183	183	183	183	183	183	183
mm	Bottom Slab depth	d_f =	300	300	300	300	300	300	300	300	300	300	309	309	309	309	349	349	349	349	420	420	420
mm	Bottom Slab Width	b_f =	7000	7000	7000	7000	7000	7000	7000	7000	7000	7000	7000	7000	7000	7000	7000	7000	7000	7000	7000	7000	7000
	Bottom Slab angle																						
mm	Web Height	d_w =	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900	1928	1928	1928	1928	2048	2048	2048	2048	2263	2263	2263
mm	Individual Web Thickness	b_{wi} =	500	500	500	500	500	500	500	500	500	500	500	500	500	500	500	500	500	500	500	500	700
	No. of Webs	No. Webs =	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
		No. of ducts in single web	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		duct diameter	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	effective web thickness	$b_{w,eq}$ =	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1400
mm	Effective web thickness shear	$b_{w,eq}$ =	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1400
m²	Full cross sectional Area	A =	9.43	9.43	9.43	9.43	9.43	9.43	9.43	9.43	9.43	9.43	9.52	9.52	9.52	9.52	9.92	9.92	9.92	9.92	10.63	10.63	11.54
MPa	Characteristic concrete strength	f_{ck} =	45	45	45	45	45	45	45	45	45	45	45	45	45	45	45	45	45	45	45	45	45
MPa	Mean concrete Tensile strength	f_{ctm} =	3.51	3.51	3.51	3.51	3.51	3.51	3.51	3.51	3.51	3.51	3.51	3.51	3.51	3.51	3.51	3.51	3.51	3.51	3.51	3.51	3.51
MPa	Characteristic steel strength	f_{yk} =	500	500	500	500	500	500	500	500	500	500	500	500	500	500	500	500	500	500	500	500	500
	Concrete Material factor	γ_c =	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5
	Steel Material factor	γ_s =	1.15	1.15	1.15	1.15	1.15	1.15	1.15	1.15	1.15	1.15	1.15	1.15	1.15	1.15	1.15	1.15	1.15	1.15	1.15	1.15	1.15
	Alpha factor for long term effects		1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1

A quicker way?

Midas is capable of PSC design.

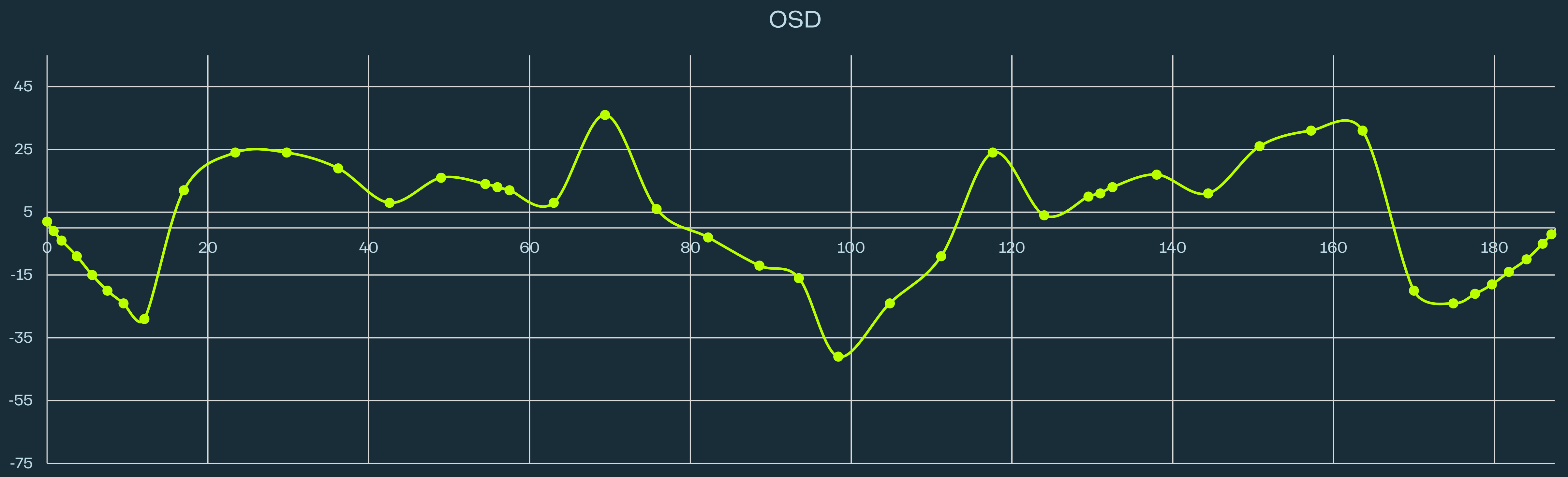
Due to contractual limitations this was not an option on this project.

Precamber

Automated by Midas

Under the results tab there is a feature called Camber/ reaction.

The tool enables quick calculation of the displacements which need to be offset during construction.



Secondary models

Abutments

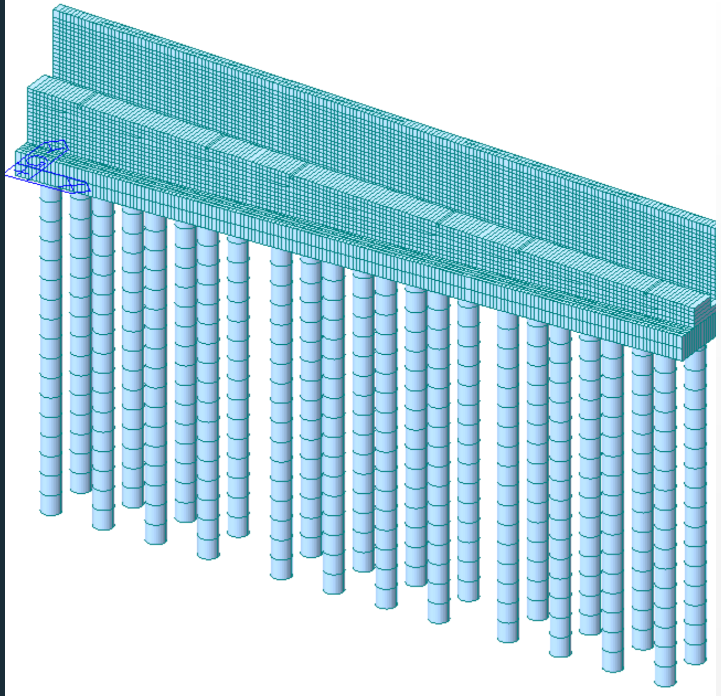
2d plate models on one-way springs

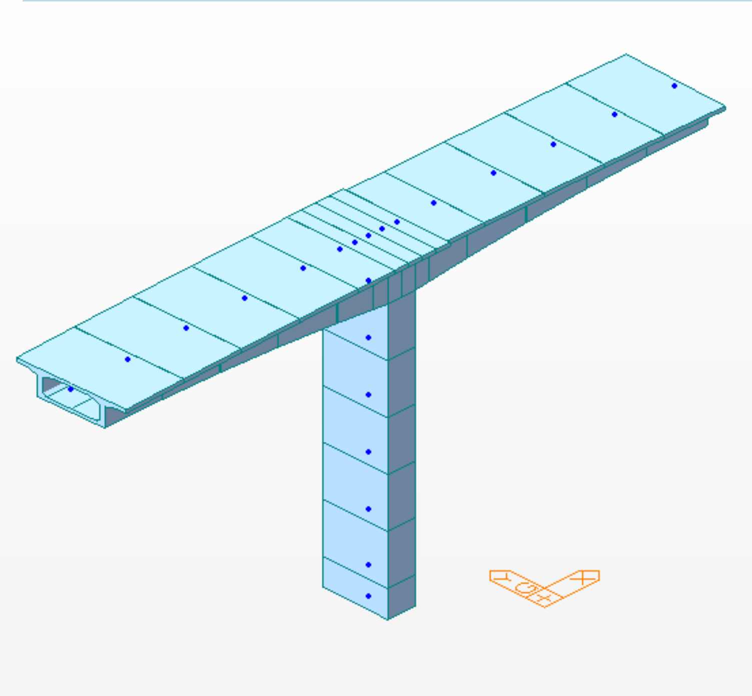
Post tension box

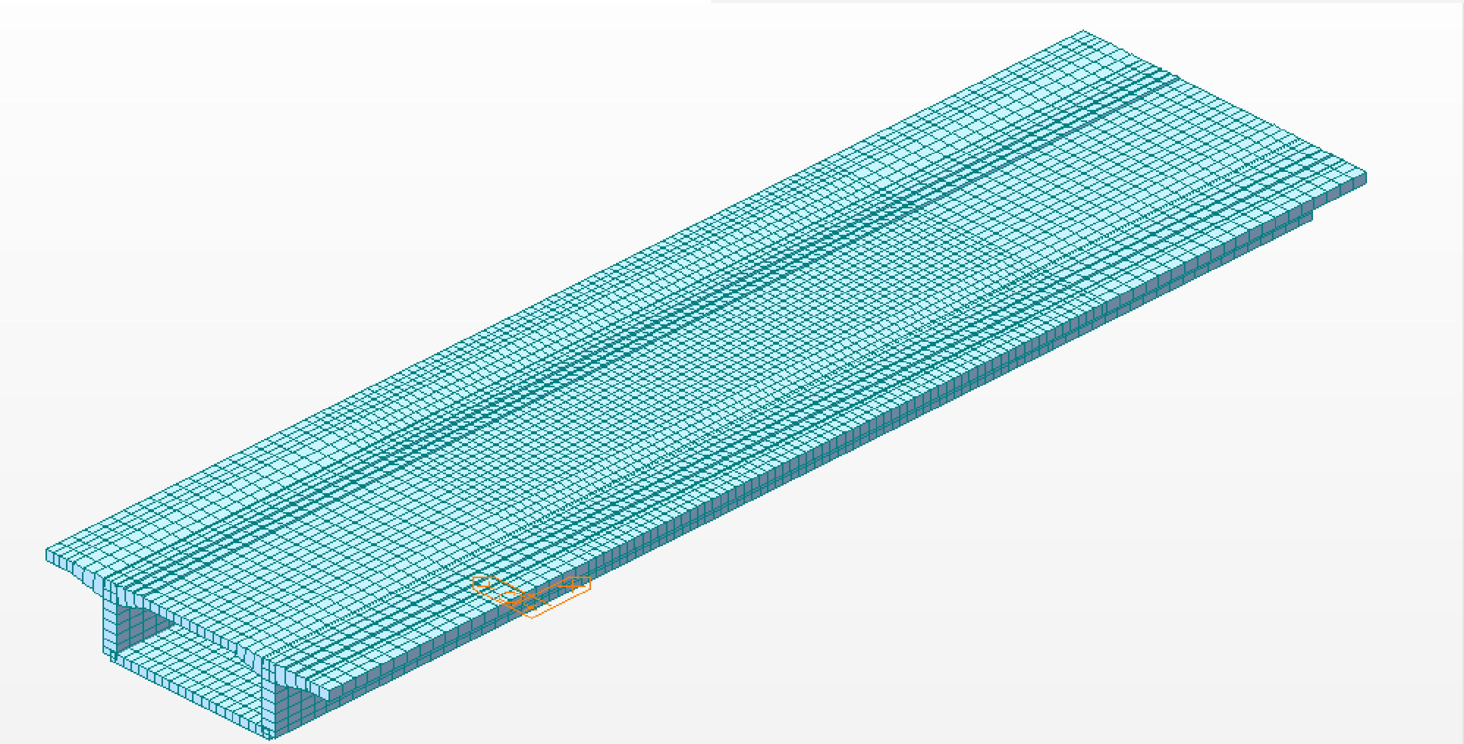
2d plate model for local effects

Natural Frequency Model

During construction dynamic wind effects can excite the unfinished bridge. A natural frequency model was required.







Changing the construction sequence…

Construction Challenges

East Pier behind schedule

Excavation on the east side proved problematic on site and fell behind program.

The structure was on the critical path, and a 3-month delay would incur significant financial penalties.

Remodelling

Mirroring the bridge

As the design was unsymmetrical this was not a simple mirror.

Changes had to take place to nearly all construction stages.

Results had key differences, as construction had already begun the design was pushed to high utilisations.

Running traffic on an unfinished bridge

Opening the onslip

To make up for lost time elsewhere it was beneficial to run traffic on the onslip prior to the deck being stitched between the eastbound and westbound.

Success?

Delivered early

The sequence change gained 3 months, and the efficient construction led to the strucutre finishing ahead of schedule.

On budget

Early contractor involvement saw off many issues long before they got to site.

Spans met in the middle

Designed for a deviation of 10mm, actual deviation achieved on site of 1mm.

Any Questions?

thank you

AtkinsRéalis