SUMMER INTERNSHIP REPORT

Construction of Missing Link with Viaduct from km 0+000 to 13+300 & Upgradation to 8 lanes from km 32+800 km to 38+660 km under capacity augmentation of Mumbai Pune Expressway in the state of Maharashtra under EPC mode

[Internship Period:- 12th May 2024 to 12th July 2024]

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ACKNOWLEDGEMENT

I am profoundly grateful to all those who have contributed to the successful completion of my internship and this report. First and foremost, I would like to express my deepest appreciation to **Dr. Srinivas Mantrala**, Professor at Indian Institue of Technology, Kanpur for providing me with the opportunity to undertake this internship at AFCONS.

My sincere gratitude goes to **Mrs. Saugata Bhattacherjee**, my internship mentor, for her continuous guidance, support, and insightful feedback throughout the internship period. Her expertise and willingness to share knowledge was instrumental in enhancing my learning experience.

I would also like to thank all the staff at AFCONS, especially the members of the Design Department, for their cooperation and assistance. Their willingness to help and share their professional experiences greatly enriched my understanding of the field.

Additionally, I am thankful to **Mr. Avinash Patil**, the HoD of the Design Department at AFCONS for his encouragement and advice, which was crucial in securing this internship and in the preparation of this report. The hands-on experience and exposure to practical civil engineering practices were invaluable.

Lastly, I would like to acknowledge the support of my family and friends, whose encouragement and support have been a source of strength throughout my internship journey.

Thank you all.

Shambhavi Agarwal

INTRODUCTION

This internship report presents a comprehensive overview of my internship experience, focusing on the modelling and construction of cable-stayed bridges (CSBs). My primary targets during this internship were to gain an in-depth understanding of the various components involved, the structural analysis of CSBs, the mechanisms through which load transfer occurs and the construction methodology. Additionally, I aimed to explore the advantages of cable-stayed bridges and the need for these long-span structures in modern infrastructure.

To achieve these targets, I engaged in a thorough literature study, utilizing a wide range of resources. The following **resources** have been used for the study:-

1. **Book**: Cable-Stayed Bridges by Holger Svensson
2. **YouTube videos**:
    - Fan-Harp arrangement of stay cables
    - Load-transfer mechanism : https://www.youtube.com/watch?v=vHASuGfYZdc
    - MIDAS modelling : https://www.youtube.com/playlist?list=PL9qZw-lrXseRI_z176_872ERO7L1UeVOB
    - Cable force tuning : https://www.youtube.com/watch?v=ZzS1qxZr2rA
3. **MIDAS Blogs**:
    - Dynamic Analysis of Fan-Harp arrangement
    - Cable Force Optimisation
    - Unknown Load Factor

This multifaceted approach provided me with a solid foundation of theoretical knowledge of Cable-Stayed Bridges, which I was able to apply and expand upon through practical experiences during my internship.

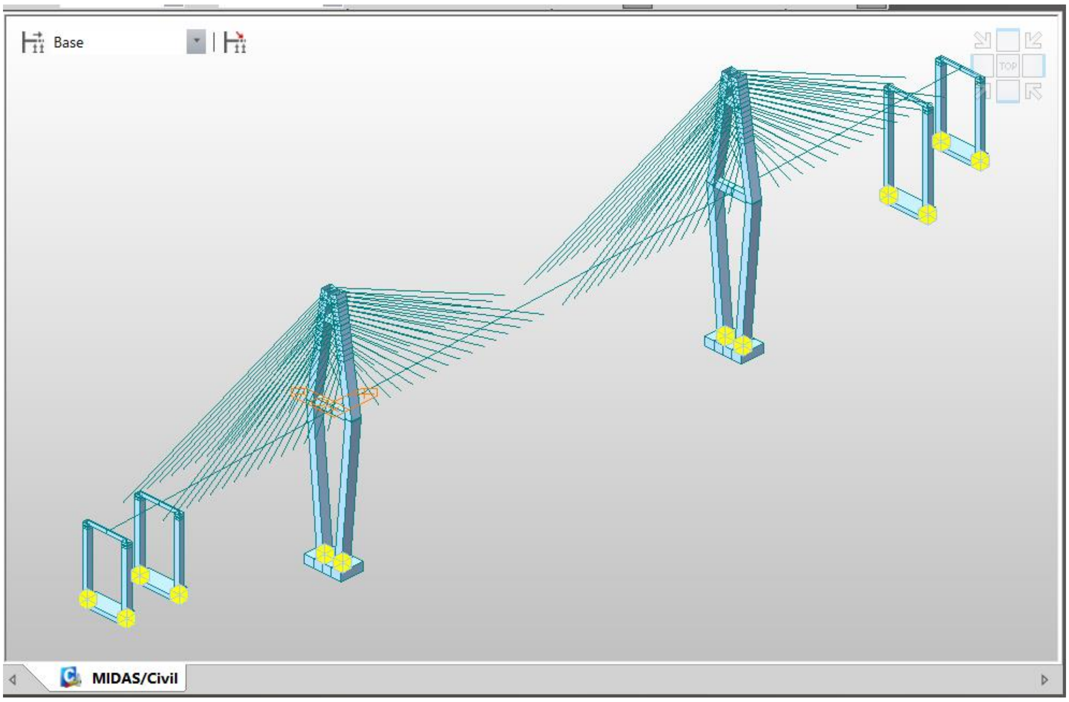
Why Cable-Stayed Bridges?

Cable-stayed bridges are ideal for long spans that are longer than cantilever bridges but shorter than suspension bridges. These longspan bridges convert the bending moments in the deck to axial forces through the stay cables. These bridges are becoming popular since 80 % of the forces and moments are taken by the cables and the remaining is taken by the deck.

The following work was done during the Internship period:-

1. Studied the General Arrangement Drawing (**GAD**)
    - Gained a holistic view of the project which involved understanding the overall layout, dimensions, and key structural elements of the cable-stayed bridge, including the locations of the pylons, deck, cables, and foundations.

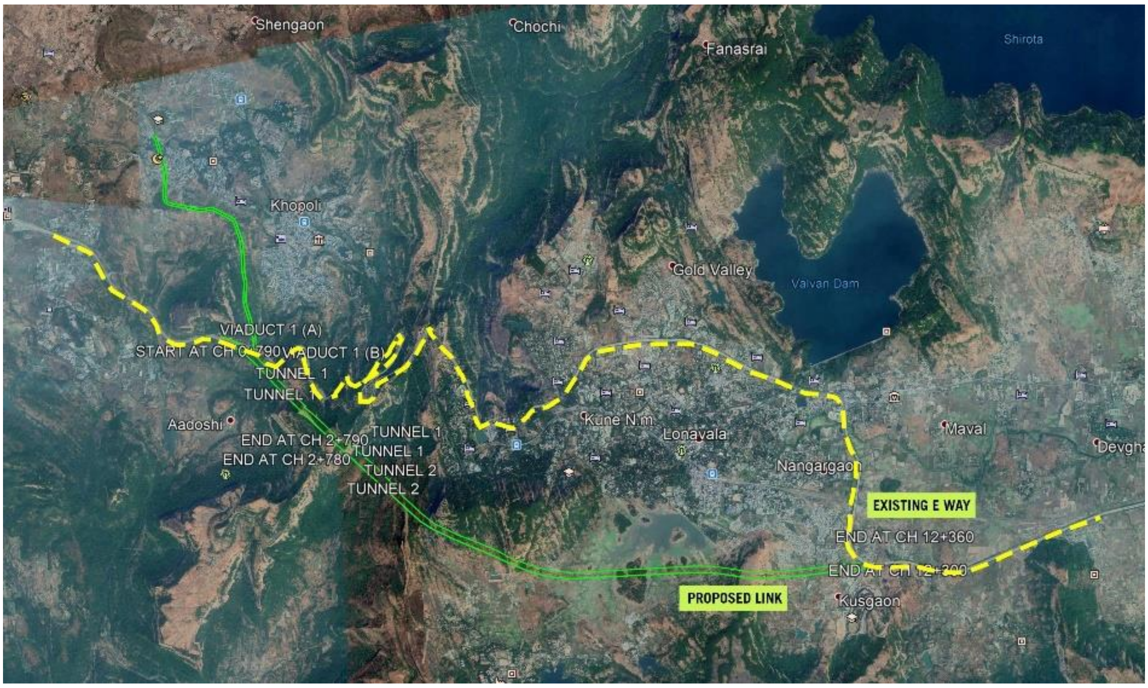
2. Created a Geometric Model Using **MIDAS** Software
    - Applying material properties to different components, such as concrete and steel.
    - Defining section properties for various parts of the bridge.
    - Applying various Loadings such as Dead Load, Live Load, Pretension Loads, Environment Loads such as Wind, Temperature and Seismic Loads.



3. Understood the **Construction Methodology**
    - With the help of a site visit, gained practical insights into the construction methodologies for both the pylon and the deck. This involved the lifting method of pylon and the balanced cantilever method for the deck.

ABOUT THE PROJECT

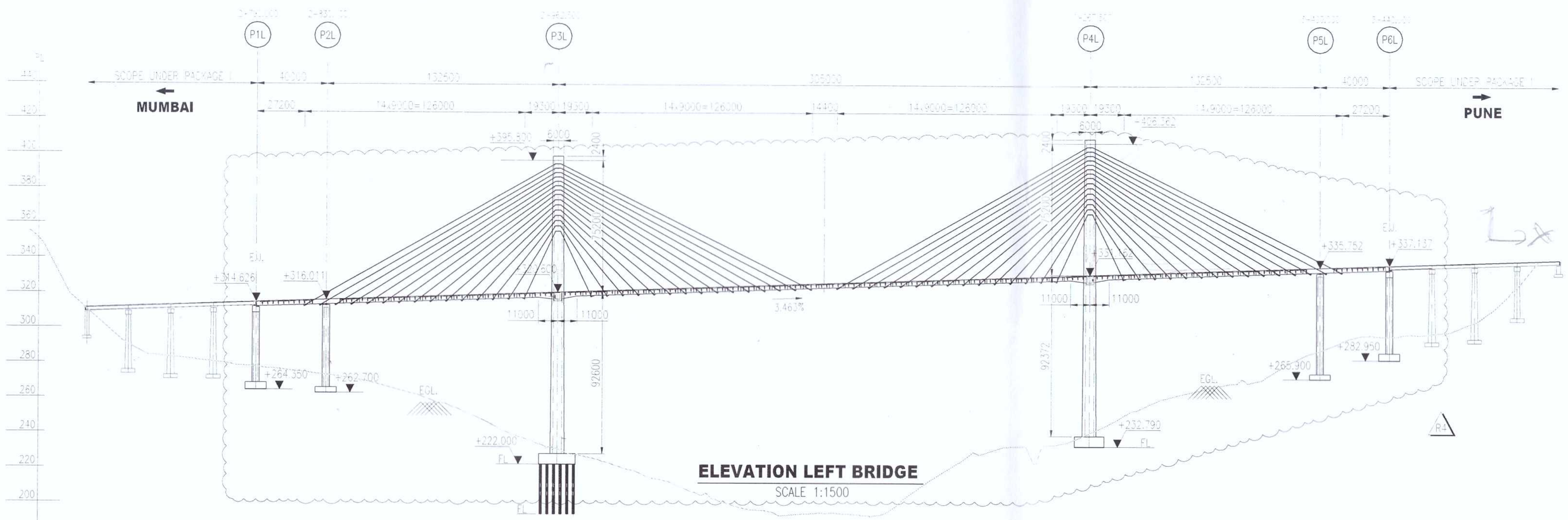
The Mumbai-Pune Expressway Missing Link Project is a landmark infrastructure initiative by the Maharashtra State Road Development Corporation (MSRDC) aimed at significantly improving connectivity and travel efficiency between Mumbai and Pune. The project's construction will shorten the Mumbai to Pune route by 7-8 kilometers and relieve traffic for about 30 minutes.



Cable-Stayed Bridge highlights:

- Total span: 650m
- Height of the Pylon: 170-180m with 100m below the deck and the remaining above the deck
- Pylons: P3L, P3R, P4L, P4R
- Piers: P1L, P1R, P2L, P2R, P5L, P5R, P6L, P6R

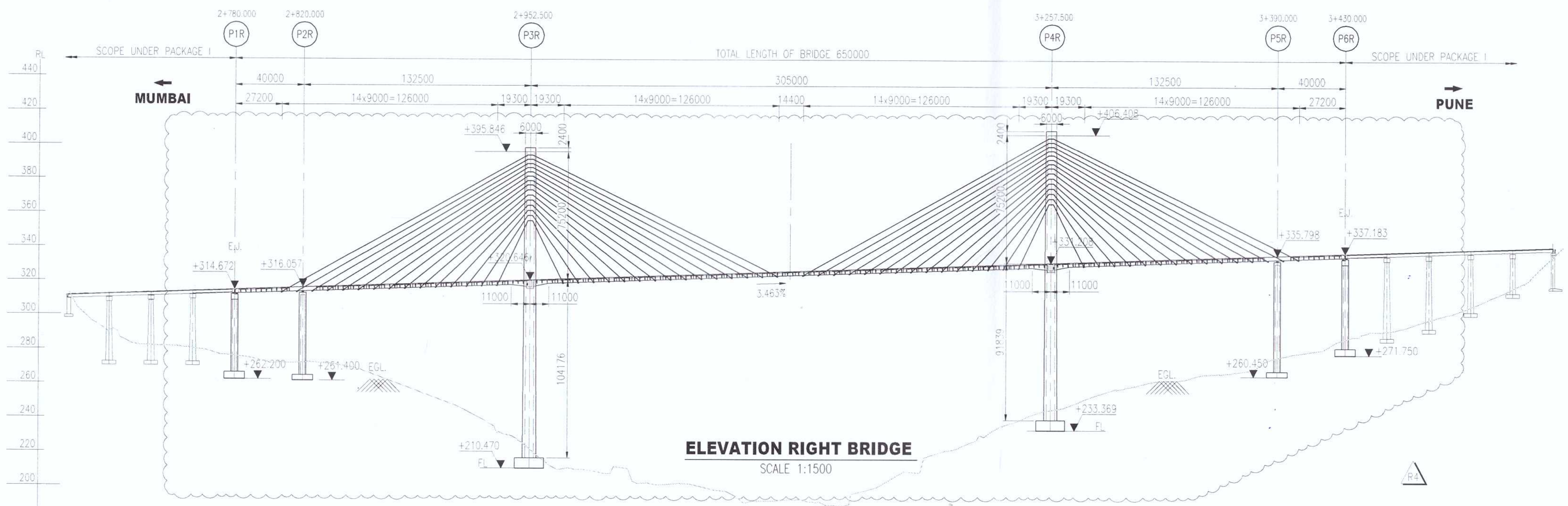
Span distance between piers P1 to P2 and P5 to P6 = 40m
Side span distance of the CSB i.e between P2 to P3 and P4 to P5 = 132.5m
Main span distance i.e between P3 and P4 = 305m



ELEVATION LEFT BRIDGE

SCALE 1:1500

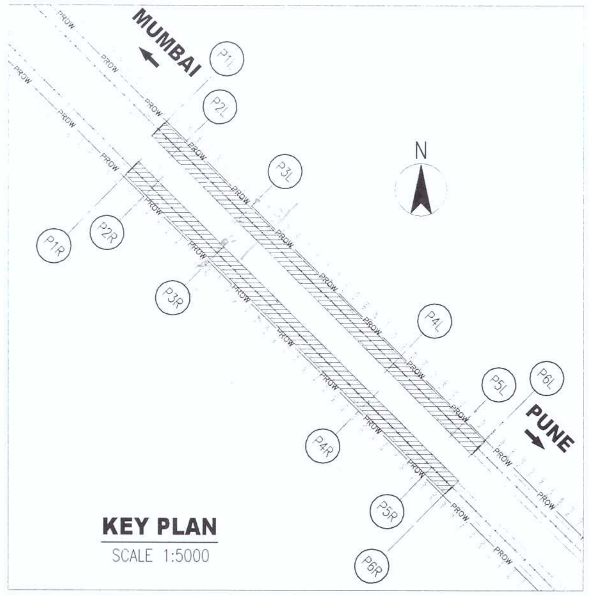
CHAINAGE	FORMATION LEVEL	EGL
2670		
2680	310.817	324.712
2690		
2700	311.509	303.972
2710		
2720	312.202	288.384
2730		
2740	312.894	283.163
2750		
2760	313.587	280.934
2770		
2780	314.280	278.250
2790		
2800	314.972	276.581
2810		
2820	315.665	274.381
2830		
2840	316.357	271.698
2850		
2860	317.050	267.712
2870		
2880	317.743	262.279
2890		
2900	318.435	256.064
2910		
2920	319.128	247.229
2930		
2940	319.820	237.852
2950		
2960	320.513	231.339
2970		
2980	321.206	226.097
2990		
3000	321.898	219.926
3010		
3020	322.591	213.624
3030		
3040	323.284	206.380
3050		
3060	323.976	199.713
3070		
3080	324.669	195.864
3090		
3100	325.361	193.688
3110		
3120	326.054	194.623
3130		
3140	326.747	192.953
3150		
3160	327.439	202.006
3170		
3180	328.132	215.733
3190		
3200	328.824	229.077
3210		
3220	329.517	232.688
3230		
3240	330.210	232.342
3250		
3260	330.902	237.195
3270		
3280	331.595	246.451
3290		
3300	332.287	256.364
3310		
3320	332.980	262.918
3330		
3340	333.673	267.484
3350		
3360	334.365	269.804
3370		
3380	335.058	279.702
3390		
3400	335.751	288.088
3410		
3420	336.443	295.900
3430		
3440	337.136	296.509
3450		
3460	337.828	297.513
3470		
3480	338.521	301.147
3490		
3500	339.214	312.067
3510		
3520	339.906	332.726
3530		
3540	340.599	350.334
3550		
3560	341.291	324.639



ELEVATION RIGHT BRIDGE

SCALE 1:1500

CHAINAGE	FORMATION LEVEL	EGL
2670		
2680	311.209	318.925
2690		
2700	311.902	294.020
2710		
2720	312.594	283.052
2730		
2740	313.287	281.840
2750		
2760	313.979	279.847
2770		
2780	314.672	275.935
2790		
2800	315.365	272.061
2810		
2820	316.057	272.117
2830		
2840	316.750	270.888
2850		
2860	317.442	265.614
2870		
2880	318.135	258.215
2890		
2900	318.828	250.674
2910		
2920	319.520	241.700
2930		
2940	320.213	229.989
2950		
2960	320.906	215.538
2970		
2980	321.598	210.013
2990		
3000	322.291	208.059
3010		
3020	322.983	202.101
3030		
3040	323.676	201.834
3050		
3060	324.369	198.212
3070		
3080	325.061	190.991
3090		
3100	325.754	192.141
3110		
3120	326.446	191.004
3130		
3140	327.139	190.438
3150		
3160	327.832	202.098
3170		
3180	328.524	208.423
3190		
3200	329.217	221.943
3210		
3220	329.909	230.699
3230		
3240	330.602	239.562
3250		
3260	331.295	245.701
3270		
3280	331.987	252.460
3290		
3300	332.680	257.966
3310		
3320	333.373	262.286
3330		
3340	334.065	264.387
3350		
3360	334.758	266.812
3370		
3380	335.450	271.820
3390		
3400	336.143	278.287
3410		
3420	336.836	282.582
3430		
3440	337.528	290.168
3450		
3460	338.221	292.682
3470		
3480	338.913	298.836
3490		
3500	339.606	304.921
3510		
3520	340.299	313.225
3530		
3540	340.991	324.564
3550		
3560	341.684	343.774



KEY PLAN

SCALE 1:5000

NOTES

1. ALL DIMENSIONS IN MILLIMETRES, CHAINAGES AND ELEVATIONS ARE IN METRES UNLESS MENTIONED OTHERWISE.
2. ONLY WRITTEN DIMENSIONS MAY BE FOLLOWED, SCALING OF DRAWING IS NOT PERMITTED.
3. LEVELS AND CHAINAGES SHALL BE CROSS CHECKED BY ROAD PLAN AND PROFILE.

R4

LEGEND:

EGL – EXISTING GROUND LEVEL
EJ – EXPANSION JOINT
RL – REDUCED LEVEL
FL – FOUNDING LEVEL

2120-TT-HW-XX-PNP-CH-30132	LHS MISSING LINK CARRIAGEWAY PROFILE FROM CH-2+000 TO 3+000
2120-TT-HW-XX-PNP-CH-30133	RHS MISSING LINK CARRIAGEWAY PROFILE FROM CH-2+000 TO 3+000
2120-TT-HW-XX-PNP-CH-30135	LHS MISSING LINK CARRIAGEWAY PROFILE FROM CH-3+000 TO 4+000
2120-TT-HW-XX-PNP-CH-30136	RHS MISSING LINK CARRIAGEWAY PROFILE FROM CH-3+000 TO 4+000
2120-TT-V2-XX-GA-CB-40001	GAD FOR EXTENDED PORTION OF V2 LHS & RHS SHEET 1 OF 4
2120-TT-V2-XX-GA-CB-40001	GAD FOR EXTENDED PORTION OF V2 LHS & RHS SHEET 2 OF 4

R4	06.03.2023	4	REVISION AS CLOUDED	LC
R3	26.01.2022	4	REVISION AS CLOUDED	JC
R2	16.12.2021	4	REVISION AS CLOUDED	TG
R1	22.10.2021	4	UPDATED ACCORDING TO COMMENTS	TG
R0	28.09.2021	4	FOR APPROVAL TO PC	TG

T. GRAAF
E. HUANG Easvin Huang
J. HUANG
B. MEMBER
28.09.2021

VIADUCT II - ELEVATION

ML-DD-GA-002

SHEET 2 OF 8

R4

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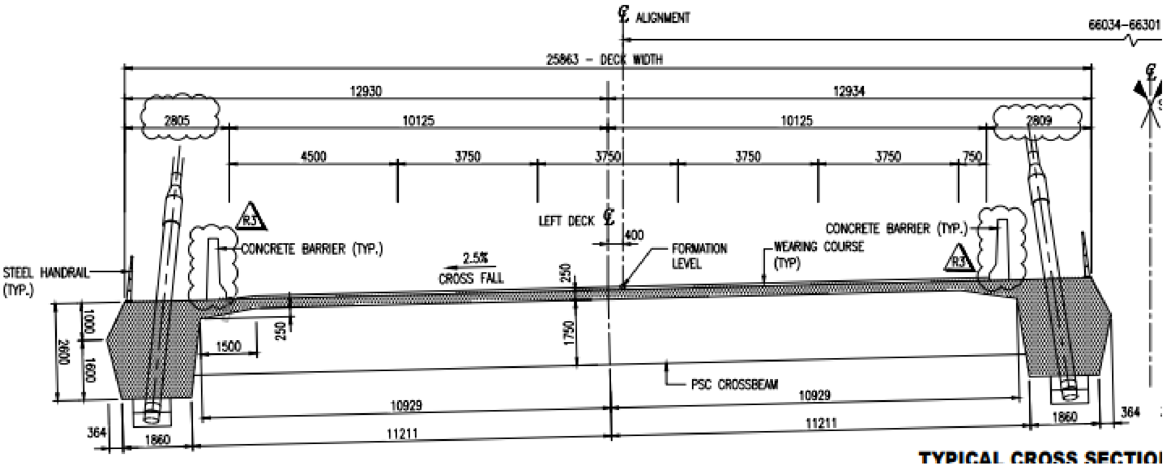
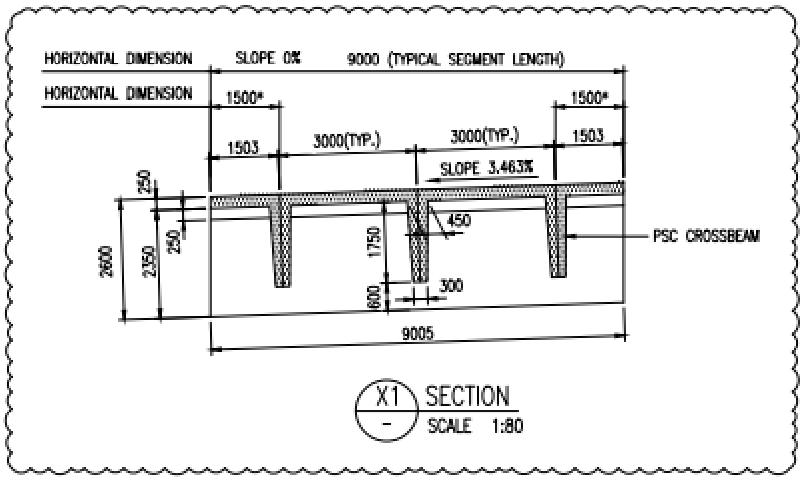
ABOUT DECK/SUPERSTRUCTURE

Characteristic features of deck:

- Deck width – 25.863m
- Deck thickness – 250mm
- 2 Edge Beams – Solid Cross section of 2.6m height × 2m width
- 15 stay cables attached on each side of Pylon spaced at 9m intervals on the deck.



The deck features two edge beams connected through cross beams. These cross beams are spaced at 3m intervals along the deck, providing structural support and stability. Each cross beam has a T-shaped cross-section, optimizing the distribution of loads across the deck. Additionally, the deck is transversely prestressed along the cross beams, enhancing its strength and increasing its shear capacity minimizing potential cracking under various loading conditions.



ABOUT STAY CABLES

The stay cables of the bridge consist of multiple strands, each 15.7mm in diameter. The number of strands varies from 30 to 80, depending on the axial loads they must support, resulting in different cross-sectional areas. Cables near the pylon carry lower axial loads, requiring fewer strands and a smaller sectional area. Conversely, cables farther from the pylon support higher axial loads, necessitating more strands and a larger sectional area to ensure structural integrity.

P3L : LEFT LEG

CABLE No.	DECK SIDE COORDINATE			PYLON SIDE COORDINATE			STRAND No.	ANCHOR	STAY PIPE SIZE (mm)	STRAND NOMINAL AREA (mm^2)	CABLE NOMINAL AREA (mm^2)	α° (NO SAG)	β° (NO SAG)	θ° (NO SAG)	γ° (NO SAG)	CABLE LENGTH (m) (NO SAG)
	X(m)	Y(m)	Z(m)	X(m)	Y(m)	Z(m)										
S01L	153.200	1.935	12.591	171.150	40.754	9.817	33	6-37	180	150	4950	64.93	25.07	8.78	4.09	42.858
S02L	144.200	1.623	12.591	171.150	43.754	9.406	31	6-37	160	150	4650	57.21	32.79	6.74	4.32	50.115
S03L	135.200	1.311	12.591	171.150	46.754	8.994	31	6-37	160	150	4650	51.51	38.49	5.71	4.52	58.055
S04L	126.200	1.000	12.591	171.150	49.754	8.583	38	6-43	180	150	5700	47.21	42.79	5.09	4.70	66.435
S05L	117.200	0.688	12.591	171.150	52.754	8.172	41	6-55	180	150	6150	43.89	46.11	4.68	4.85	75.107
S06L	108.200	0.376	12.591	171.150	55.754	7.760	41	6-43	180	150	6150	41.26	48.74	4.39	4.98	83.981
S07L	99.200	0.065	12.591	171.150	58.754	7.349	48	6-55	200	150	7200	39.13	50.87	4.17	5.10	92.999
S08L	90.200	-0.247	12.591	171.150	61.754	6.938	48	6-55	200	150	7200	37.38	52.62	3.99	5.21	102.122
S09L	81.200	-0.559	12.591	171.150	64.254	6.595	50	6-55	200	150	7500	35.71	54.29	3.81	5.29	111.030
S10L	72.200	-0.870	12.591	171.150	66.754	6.252	50	6-55	200	150	7500	34.29	55.71	3.67	5.35	120.018
S11L	63.200	-1.182	12.591	171.150	69.254	5.909	58	6-61	225	150	8700	33.07	56.93	3.54	5.42	129.070
S12L	54.200	-1.494	12.591	171.150	71.754	5.567	63	6-73	225	150	9450	32.01	57.99	3.44	5.48	138.173
S13L	45.200	-1.805	12.591	171.150	74.254	5.224	77	6-85	250	150	11550	31.08	58.92	3.35	5.53	147.318
S14L	36.200	-2.117	12.591	171.150	76.754	4.881	76	6-85	250	150	11400	30.26	59.74	3.27	5.58	156.498
S15L	27.200	-2.429	12.591	171.150	79.254	4.538	76	6-85	250	150	11400	29.53	60.47	3.20	5.63	165.706

Why are cables used and not a simple solid rod?

A cable consists of numerous strands whereas a rod has a solid cross-section. Due to these small diameter strands, the moment of inertia of a cable reduces drastically thus reducing the bending capacity. Hence, cables cannot take bending moments but can withstand high axial forces. But, this comes with a trade-off. We often get the strength of the rod in the range of 500 - 600 MPa. But due to the strain hardening phenomenon of steel, the strength of cables can be obtained as high as 1800-2000 MPa which allows us to use cable elements to withstand huge axial forces.

Figure 2. Cable vs Rod

ARRANGEMENT OF CABLE-STAYS

There are 3 basic arrangements of cable-stays:-

- **Fan** arrangement – All cables join at the tower head.
- **Harp** arrangement – All cables run parallel and are anchored over the height of the tower.
- **Fan-Harp** arrangement – This is an intermediate arrangement between the fan and harp configurations.

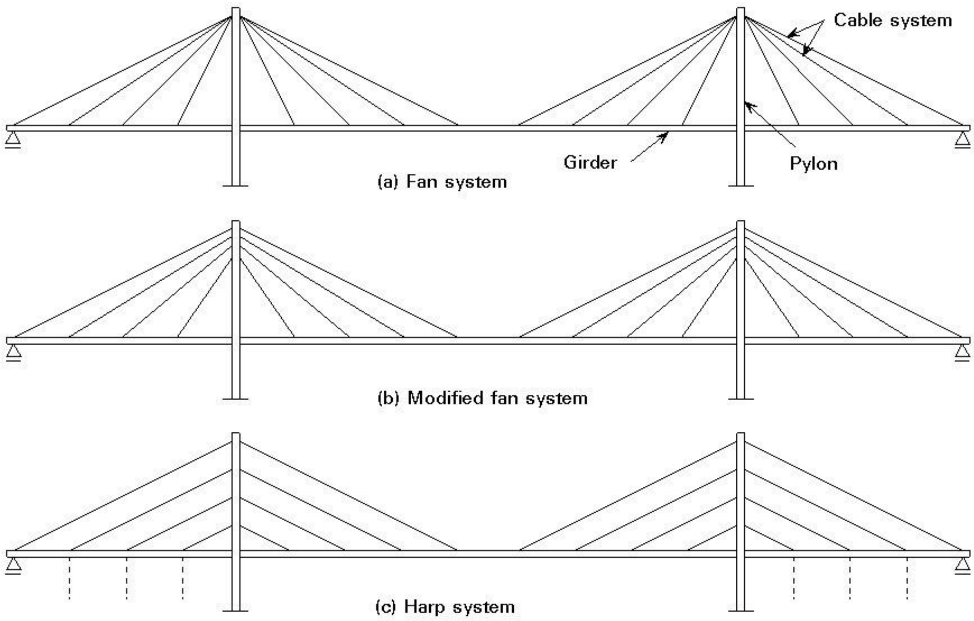


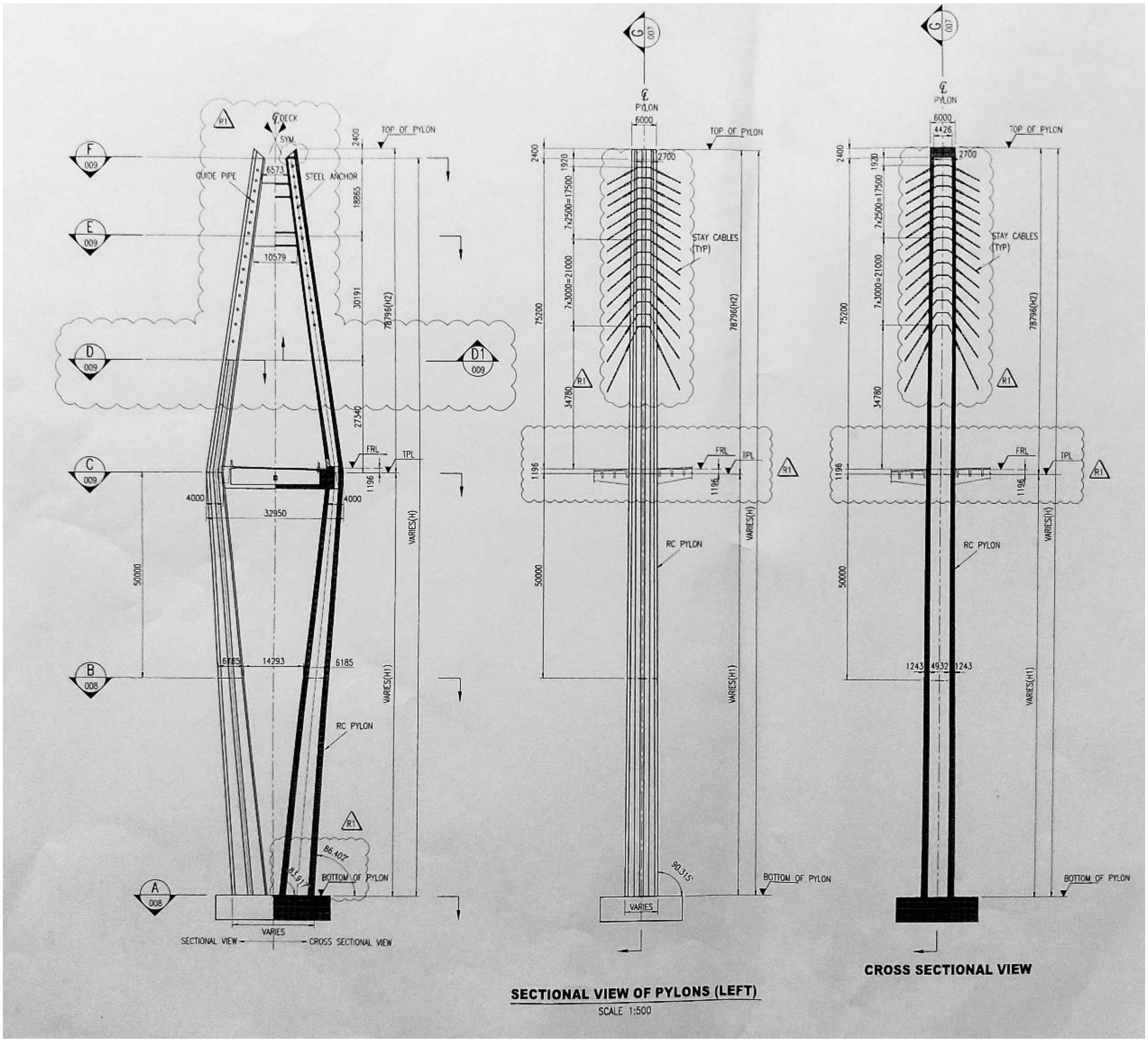
Figure 1 Types of cable stayed bridge

The true fan arrangement is impractical because each cable must be individually replaceable in case of damage, requiring minimum distances between cable anchorages at the tower head.

In the harp arrangement, the ratio of vertical to horizontal forces is less compared to the fan arrangement due to its less angle of inclination. More vertical forces in the fan arrangement mean more forces and moments from the deck are transferred to the cables. Therefore, an intermediate fan-harp arrangement is often used to balance these forces.

ABOUT PYLONS

The bridge features diamond-shaped pylons made of reinforced concrete with hollow, tapering sections. This design enhances both aesthetics and structural efficiency by increasing inertia and reducing weight with less concrete. The hollow sections improve stability, especially at higher elevations where wind effects are strong. Rigid connections to the deck ensure a stable and strong link, crucial for the bridge's integrity and load distribution.



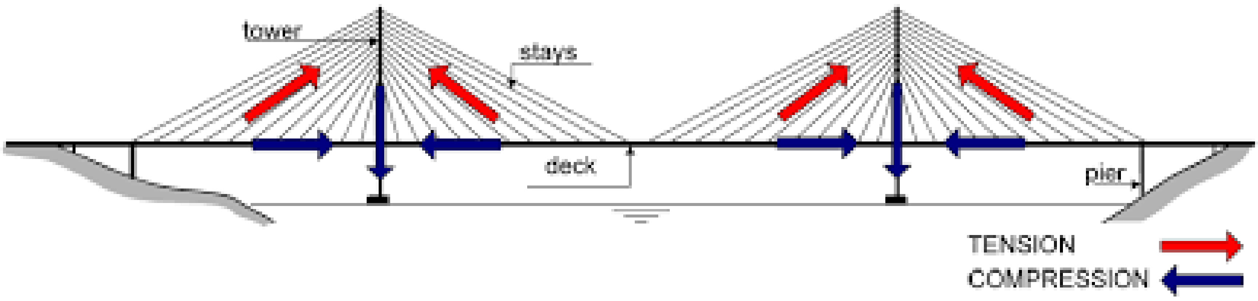
Pylon foundation :-

The ground in the vicinity of the bridge is with moderately weathered and moderately strong rock rock at all support locations except for Pylon at P3L. Therefore, raft foundation is adopted except at P3L, where pylon is supported by 42 piles of 1.5m diameter casted 28m deep in the ground.

LOAD TRANSFER MECHANISM

In cable-stayed bridges, the deck is supported by stay cables at regular intervals, allowing the dead and live loads acting on the deck to be transferred to the stays. This reduces the effective deck span to the distance between the stay points, which, in turn, reduces the bending moments and shear forces in the deck. As a result, the deck section can be made thinner, significantly reducing the overall dead weight of the structure. Consequently, two main beams with dimensions of 2.6 meters deep by 2 meters wide at the edges are sufficient for a 305-meter main span.

Since the deck is supported by stay cables, the loads from the deck are transferred to the stays as tensile forces. Because the cables are under axial tension, they are made of steel due to its high tensile strength. The other end of the stay cables is connected to the pylon, and this tension in the cables creates a compressive force in the pylons. Therefore, the pylons are constructed using high-strength (M60 grade) concrete, which has high compressive strength. This axial compressive force in the pylons is then transferred to the foundation.



As the cable stays are inclined, the axial force at the bottom end creates a compressive force in the deck. This compressive force in the deck further generates a prestressing force, which helps reduce the deck section. The inclination of the cable stays at the upper end, where they connect to the pylon, creates a horizontal force on the pylon. The stay cables on both sides of the pylon maintain equilibrium by balancing the forces within the structure. Therefore, it is important for the cable-stayed bridge to have spans on both sides of the pylon.

CABLE FORCE OPTIMISATION

The deck is supported by the stay cables, which develop tension. Due to this tension, the stays elongate, causing the deck to deflect downward. To avoid this deflection, we apply a pretension force to the stay cables. This pretension force should be just sufficient to keep the deck near its original position.

If we apply too much pretension force, it will lift the deck, while applying too little will allow the deck to deflect downward. We want to avoid both scenarios, so to find the optimum force in the stays, we use deflection as a constraint. This process is called cable force optimization.

By employing an optimization technique, a solution that satisfies the equality and inequality conditions is obtained. Numerous solutions to the unknown loads exist, depending on the constraints imposed on these conditions. The software finds a solution to the equality and inequality conditions by utilizing variables that minimize the specified objective functions. Midas Civil allows users to choose from various objective functions, including the sum of absolute values, the sum of squares, and the maximum absolute values of the variables. These variables represent the **Unknown Load Factors**.

Reference: Midas Help Manual

Object Function type: Select the method of forming an object function consisted of unknown load factors.

Linear: The sum of the absolute values of Load factor x weight

$$Obj. = \sum_{i=1}^{n} |T_i \times W_i|$$

Square: The linear sum of the squares of Load factor x weight

$$Obj. = \sum_{i=1}^{n} (T_i \times W_i)^2$$

Max Abs: The maximum of the absolute values of Load factor x weight

$$Obj. = Maximum(|T_1 W_1|, |T_2 W_2|, \cdots |T_n W_n|)$$

The following procedure is adopted:-

1. Define the constraints and obtain the Unknown Load Factors for the Cable Pretension Forces.
2. Determine the Cable Pretension Force by multiplying those factors with the assigned Cable Forces.
3. Change the Cable Pretension Forces with the new ones (Obtained in step 2).
4. Perform Analysis.

In this model, unit pretension is initially applied to the cables, and the forces, moments and deformations are found correspondingly.

Then, a constraint of 20 mm on the deflection of the nodes at the deck is applied.

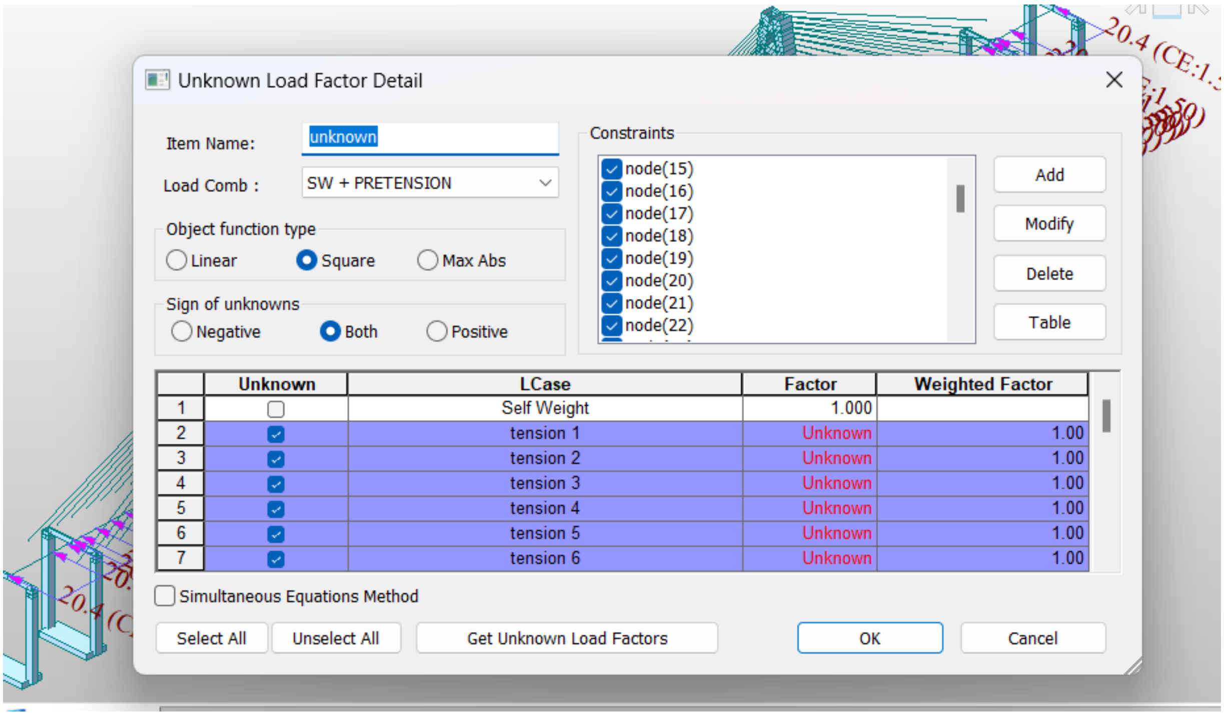
Constraint Table

Reaction | Displacement | Truss Force | Beam Force

	Name	Node	Compo.	Type	Value	(O)	Other	(U)	Upper	(L)	Lower
1	node(15)	105	DZ	Inequality		☐		☑	20	☑	-20
2	node(16)	106	DZ	Inequality		☐		☑	20	☑	-20
3	node(17)	107	DZ	Inequality		☐		☑	20	☑	-20
4	node(18)	108	DZ	Inequality		☐		☑	20	☑	-20
5	node(19)	109	DZ	Inequality		☐		☑	20	☑	-20
6	node(20)	110	DZ	Inequality		☐		☑	20	☑	-20
7	node(21)	111	DZ	Inequality		☐		☑	20	☑	-20
8	node(22)	112	DZ	Inequality		☐		☑	20	☑	-20
9	node(23)	113	DZ	Inequality		☐		☑	20	☑	-20
10	node(24)	114	DZ	Inequality		☐		☑	20	☑	-20
11	node(25)	115	DZ	Inequality		☐		☑	20	☑	-20
12	node(26)	116	DZ	Inequality		☐		☑	20	☑	-20
13	node(27)	117	DZ	Inequality		☐		☑	20	☑	-20
14	node(28)	118	DZ	Inequality		☐		☑	20	☑	-20
15	node(29)	119	DZ	Inequality		☐		☑	20	☑	-20
16	node(30)	120	DZ	Inequality		☐		☑	20	☑	-20
17	node(31)	121	DZ	Inequality		☐		☑	20	☑	-20
18	node(32)	122	DZ	Inequality		☐		☑	20	☑	-20
19	node(33)	123	DZ	Inequality		☐		☑	20	☑	-20
20	node(34)	124	DZ	Inequality		☐		☑	20	☑	-20

Close

The Unknown Load Factors for the pretension force are then found out using these constraints.



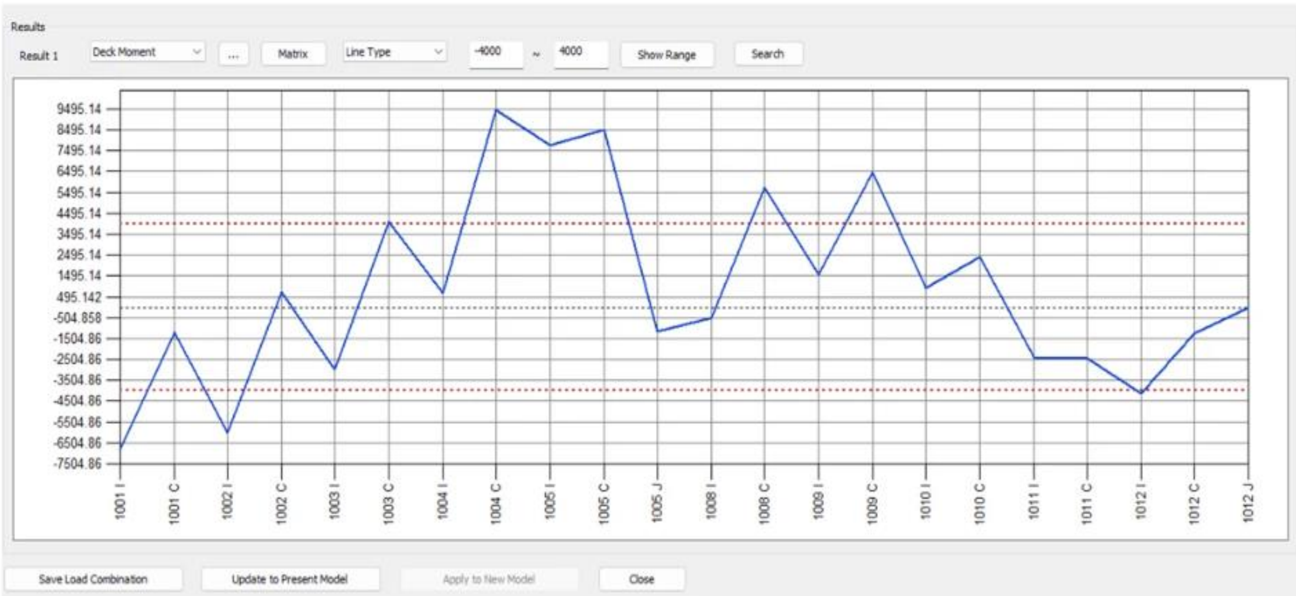
By clicking on “Get Unknown Load Factors”, an Excel sheet is extracted containing the **Influence Matrix**. The values in the red box are the factors with which the cable forces need to be multiplied. Since unit pretension was initially applied, these values become the exact pretension forces that need to be applied. The “Value” row gives the deformations at those particular nodes when the modified pretension loads are applied.

The Influence Matrix gives the deformation at a particular node corresponding to a particular tension.

	Constraint	node(15)	node(16)	node(17)
Factor	Upper Bound	0.02	0.02	0.02
	Lower Bound	-0.02	-0.02	-0.02
	Value	-0.01999109	-0.02	-0.019692386
Self Weight	1	-0.028845133	-0.026529557	-0.025503571
tension 1	873.174017	7.2208E-07	7.53185E-07	7.68704E-07
tension 2	1028.167215	7.06596E-07	8.18011E-07	8.5509E-07
tension 3	1170.259928	6.65464E-07	7.83117E-07	8.92581E-07
tension 4	1287.093759	6.03743E-07	7.15403E-07	8.29464E-07
tension 5	1399.191733	5.37244E-07	6.35874E-07	7.45567E-07
tension 6	1513.746874	4.68381E-07	5.49022E-07	6.48105E-07
tension 7	1608.108198	3.91915E-07	4.4989E-07	5.32499E-07
tension 8	1706.36766	3.15431E-07	3.48098E-07	4.10961E-07
tension 9	1769.523415	2.34136E-07	2.39222E-07	2.78933E-07
tension 10	1839.202636	1.54957E-07	1.31353E-07	1.46528E-07
tension 11	1881.845763	7.57002E-08	2.32727E-08	1.29272E-08
tension 12	1913.918472	-6.53028E-10	-8.13979E-08	-1.17236E-07
tension 13	1912.533404	-7.20887E-08	-1.78709E-07	-2.38585E-07

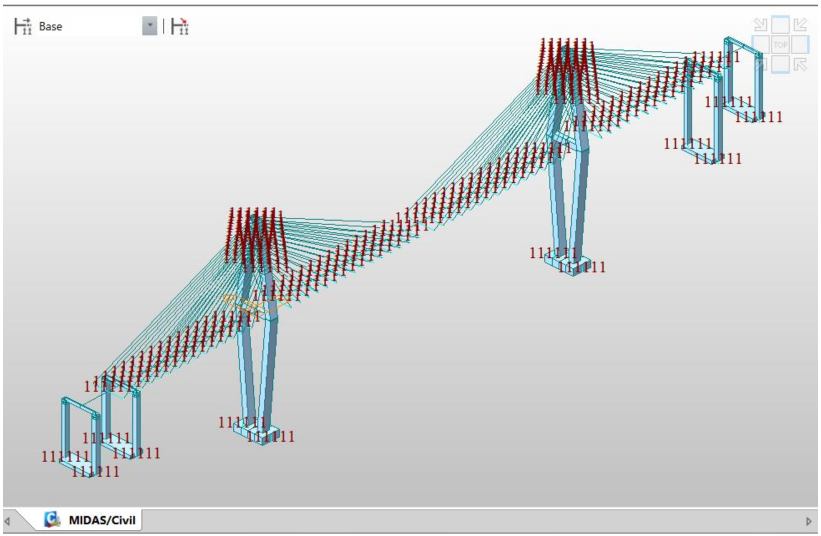
The Unknown Load Factors obtained by this method do not include the change in stiffness of the cable due to the change in pretension and hence the user must perform iterations to determine the pretension in the cables to satisfy constraints. This iteration process is made easier with the help **of Cable Force Tuning**.

In Cable Force Tuning, the user can identify the cables where the forces are either exceeding or not within a specified range. The user can then fine-tune the forces in these particular cables to ensure they are within the desired limits.



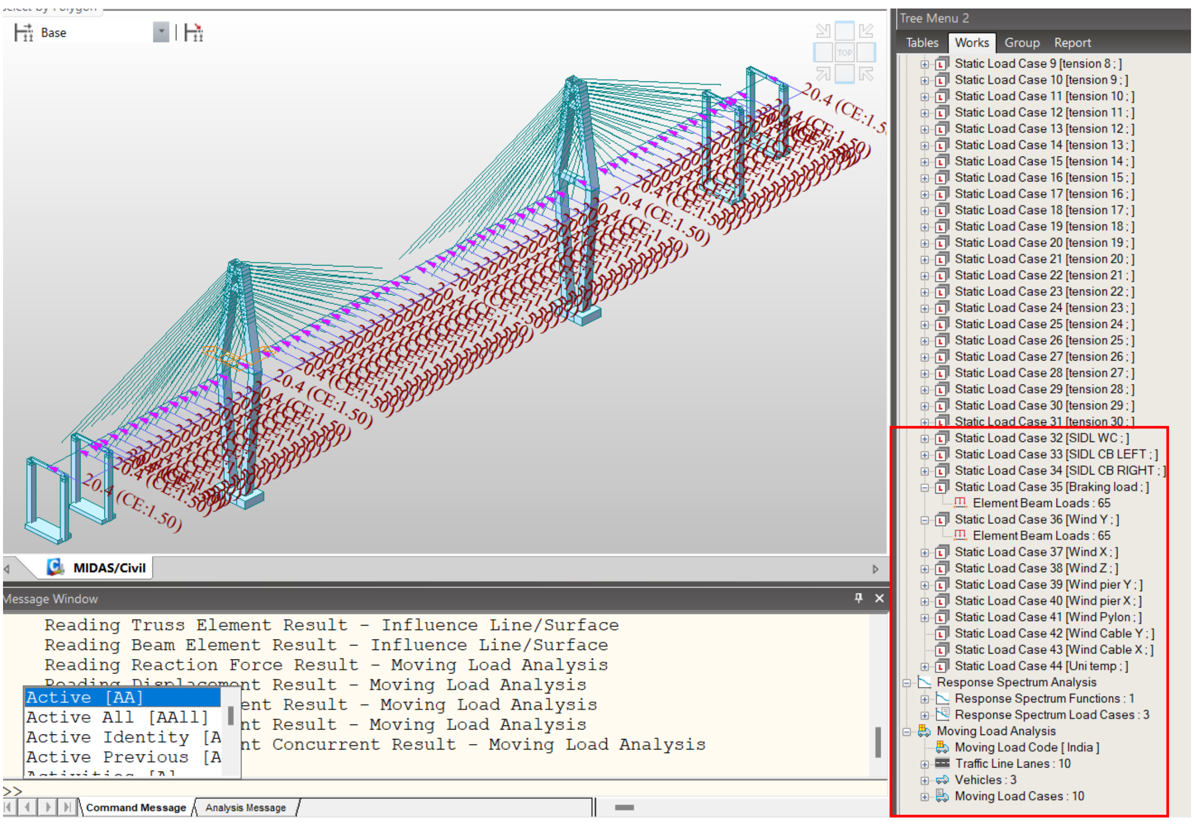
MY INVOLVEMENTS

The modelling and analysis of the Cable-Stayed Bridge was the primary focus. A geometric model for the same was created in MIDAS software using nodes and elements, with appropriate material and section properties applied.



Proper connections were established through rigid links, which were used to connect the cables to the deck and the pylon. Point spring rigid supports were provided at the foundation, supporting the structure.

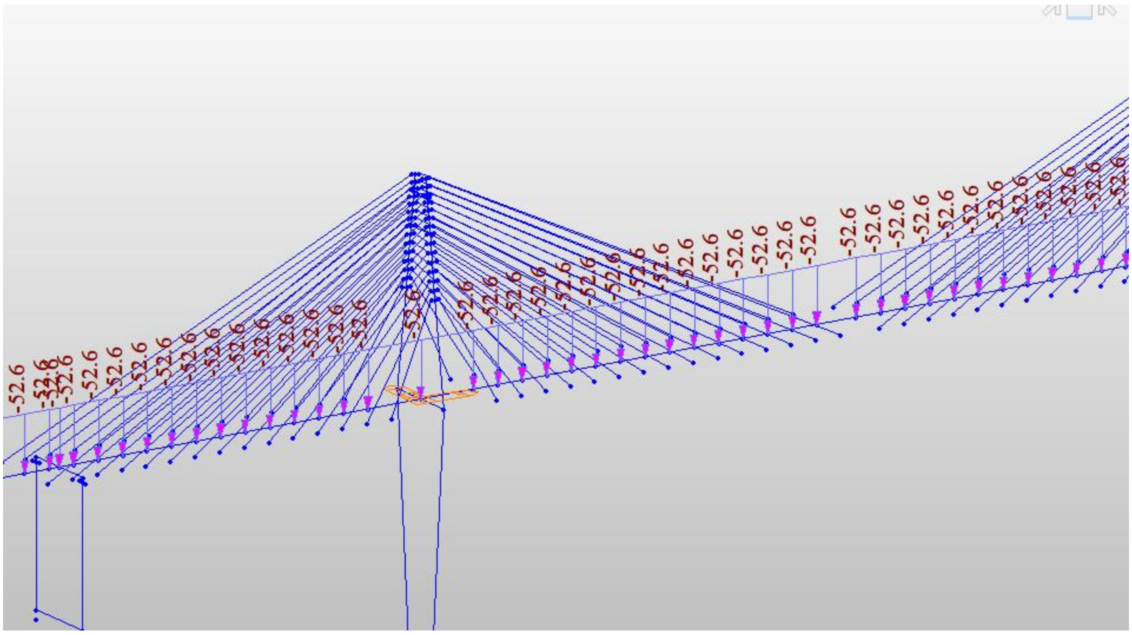
Various loadings like Dead Load, Pretension loads, SIDL (Wearing Coat + Crash Barrier), Wind load, Braking load, Live load, Uniform Temperature and Earthquake loads have been applied. These loads are applied with reference to the Design Basis Report and following the provisions of IRC:6.



Calculation of **SIDL Wearing Coat** :-

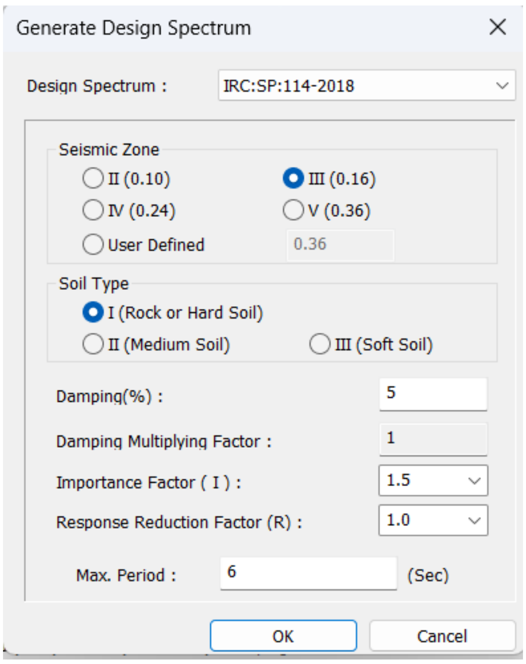
Density of bitumen = 22 kN/m^3; 80mm thick wearing coat + 12mm thick WC on walkway; deck width= 26m

Load= 22*0.092*26 kN/m = 52.6 kN/m

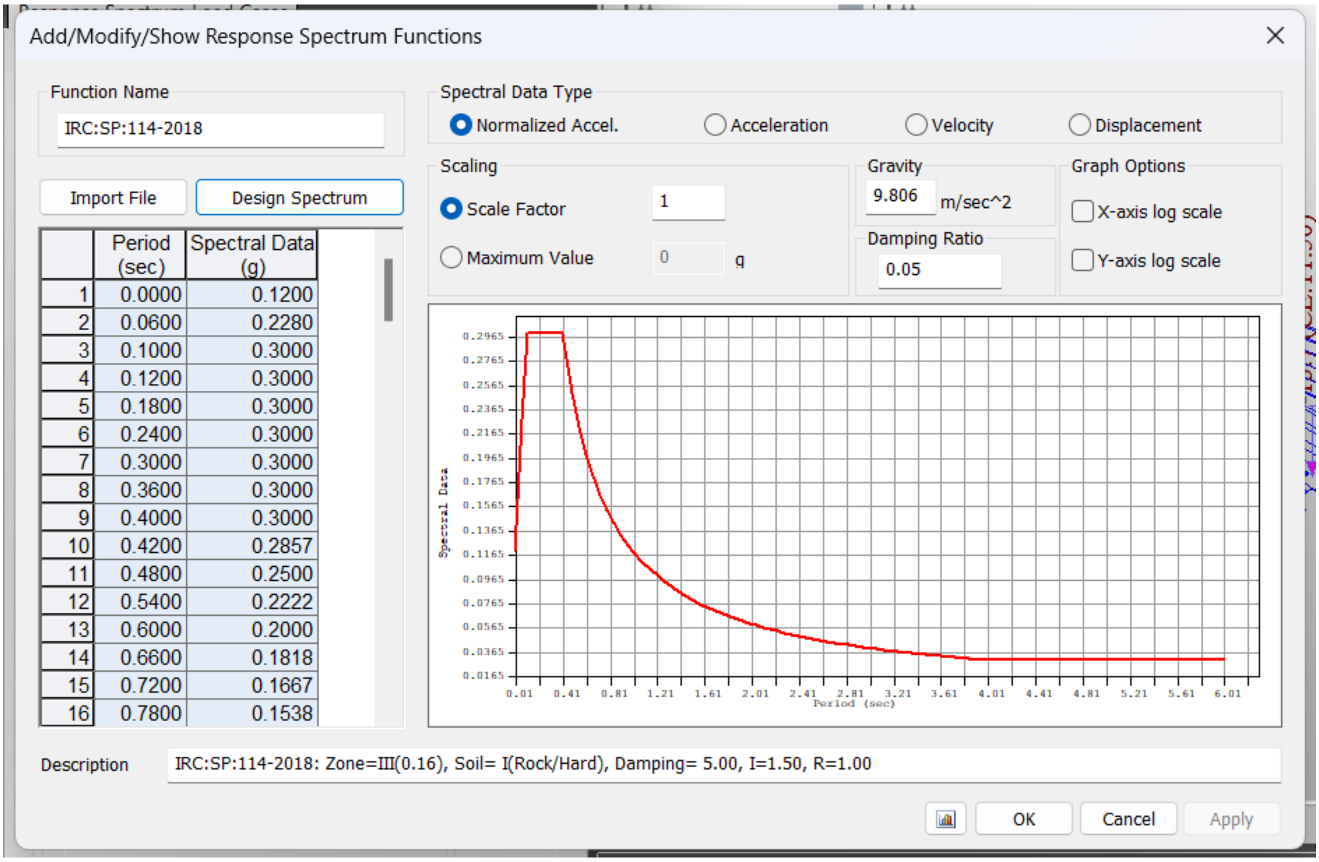


Wind loads – The effect of wind forces is tremendous and varies with height. A prototype is made that needs to pass through the wind tunnel test. The load calculations for wind forces considering the basic wind speed and the variations with height is also done on MS Excel.

For **Seismic loads**, a Response Spectrum is first created by inputting the required values of the Zone factor, Damping factor, Importance factor, Soil Type and the Response Reduction factor.



A Response Spectrum is thus created.



	Period (sec)	Spectral Data (g)
1	0.0000	0.1200
2	0.0600	0.2280
3	0.1000	0.3000
4	0.1200	0.3000
5	0.1800	0.3000
6	0.2400	0.3000
7	0.3000	0.3000
8	0.3600	0.3000
9	0.4000	0.3000
10	0.4200	0.2857
11	0.4800	0.2500
12	0.5400	0.2222
13	0.6000	0.2000
14	0.6600	0.1818
15	0.7200	0.1667
16	0.7800	0.1538

A_h = horizontal seismic coefficient = $(Z/2) \times (I) \times (S_a/g)$

In this project; Z= Zone Factor = 0.16 for Zone 3, I=1.5, R=1 (No Response Reduction)

According to IRC:6;

For rocky or hard soil sites, Type I soil with N > 30

$$\frac{S_a}{g} = \begin{cases} 1 + 15\,T, & 0.00 \le T \le 0.10 \\ 2.50 & 0.10 \le T \le 0.40 \\ 1.00/T & 0.40 \le T \le 4.00 \end{cases}$$

Putting these values of Sa/g in Ah, the above red graph is obtained with a peak of (0.16/2)*1.5*2.5 = 0.3 obtained when 0.10≤T≤0.40.

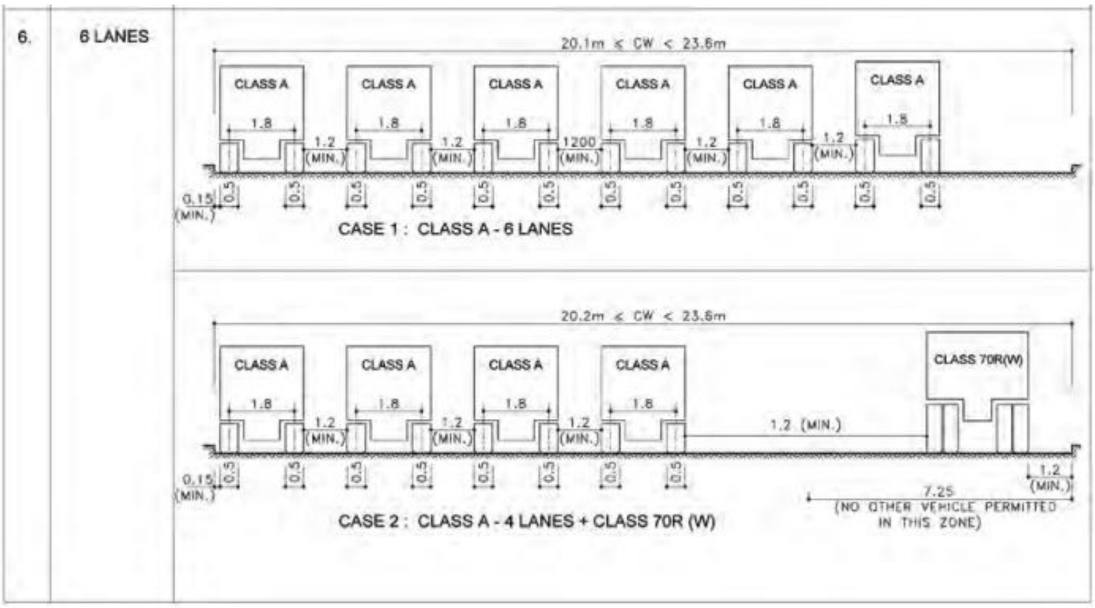
Since, Sa/g is linear when T≤0.10 implies Ah is also linear.

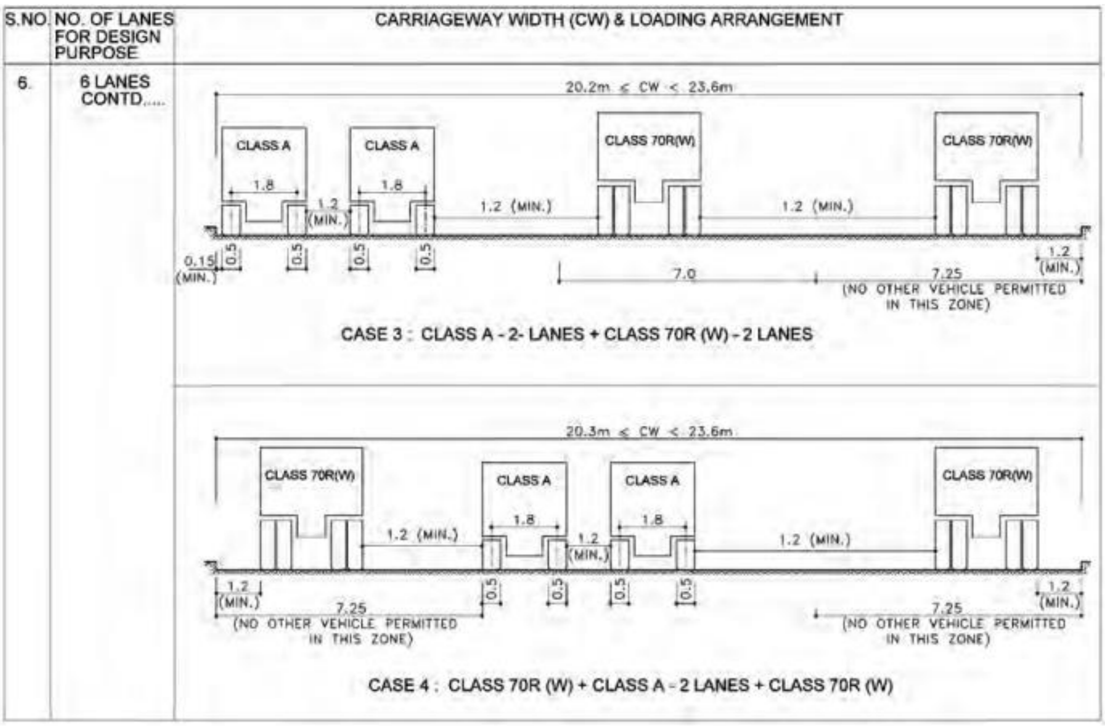
Since, Sa/g varies inversely with T when 0.4≤T≤4.0 implies Ah also follows similarly.

Hence, graph obtained by the software is verified.

Live loads

Considering the carriageway width, the bridge is designed for 6 lanes of traffic although only 4 lanes will be plying. The load combinations have been made in the software with reference to IRC:6.





The load calculation for the Braking load which considers the most critical load combination and applies the braking load for the same has been done on MS Excel.

4. Braking Force

As per IRC-6:2017 Cl. 211.2

Braking force = 20% of 1st train load + 10% of loads of succeeding trains + 5% of loads on the lanes in excess of two.

Width of Carriageway			=	23	m
Vehicle combination					
Case 1			=	6 Class A	
Case 2			=	4 Class A & 1 Class 70R W	
Case 3			=	2 Class A & 2 Class 70R W	
Case 4			=	1 Class 70R W & 2 Class A & 1 Cla	

First Vehicle load

	Vehicle	Load (kN)
Case 1	Class A	554
Case 2	70 R	1000

Last Vehicle load

Vehicle	Load (kN)
Class A	0
70 R	0

	Case	Load (kN)					
		Lane 1	Lane 2	Lane 3	Lane 4	Lane 5	Lane 6
1	6 Class A	554	554	554	554	554	554
2	4 Class A & 1 Class 70R W	1000		554	554	554	554
3	2 Class A & 2 Class 70R W	1000	0	1000	0	554	554
4	1 Class 70R W & 2 Class A & 1 Class 70R W	1000	0	554	554	0	1000

	Case	**% Load for first vehicle**					
		Lane 1	Lane 2	Lane 3	Lane 4	Lane 5	Lane 6
1	6 Class A	20.00%	0.00%	5.00%	5.00%	5.00%	5.00%
2	4 Class A & 1 Class 70R W	20.00%	0.00%	5.00%	5.00%	5.00%	5.00%
3	2 Class A & 2 Class 70R W	20.00%	0.00%	5.00%	5.00%	5.00%	5.00%
4	1 Class 70R W & 2 Class A & 1 Class 70R W	20.00%	0.00%	5.00%	5.00%	5.00%	5.00%

	Case	% Load for succeeding vehicle					
		Lane 1	Lane 2	Lane 3	Lane 4	Lane 5	Lane 6
1	6 Class A	10.00%	0.00%	5.00%	5.00%	5.00%	5.00%
2	4 Class A & 1 Class 70R W	10.00%	0.00%	5.00%	5.00%	5.00%	5.00%
3	2 Class A & 2 Class 70R W	10.00%	0.00%	5.00%	5.00%	5.00%	5.00%
4	1 Class 70R W & 2 Class A & 1 Class 70R W	10.00%	0.00%	5.00%	5.00%	5.00%	5.00%

A)	Case	**Load (kN) from first vehicle**					
		Lane 1	Lane 2	Lane 3	Lane 4	Lane 5	Lane 6
1	6 Class A	110.8	0	27.7	27.7	27.7	27.7
2	4 Class A & 1 Class 70R W	200	0	27.7	27.7	27.7	27.7
3	2 Class A & 2 Class 70R W	200	0	50	0	27.7	27.7
4	1 Class 70R W & 2 Class A & 1 Class 70R W	200	0	27.7	27.7	0	50

B)	Case	Load (kN) from succeeding vehicle					
		Lane 1	Lane 2	Lane 3	Lane 4	Lane 5	Lane 6
1	6 Class A	0	0	0	0	0	0
2	4 Class A & 1 Class 70R W	0	0	0	0	0	0
3	2 Class A & 2 Class 70R W	0	0	0	0	0	0

C)	Case	Load (kN) from last vehicle					
		Lane 1	Lane 2	Lane 3	Lane 4	Lane 5	Lane 6
1	6 Class A	0	0	0	0	0	0
2	4 Class A & 1 Class 70R W	0	0	0	0	0	0
3	2 Class A & 2 Class 70R W	0	0	0	0	0	0

Case 1 =	221.6	+ 0	+ 0	= 222	kN	
Case 2 =	310.8	+ 0	+ 0	= 311	kN	
Case 3 =	305.4	+ 0	+ 0	= 305	kN	
Case 4=	305.4	+ 0	+ 0	= 305	kN	
Maximum Braking force		=	**311**	**kN**		Applied on top of
Carraigeway Width		=	23			each pier 1.2m
Braking force per pier		=	**13.81**	**kN/m**		above the road level
Span length		=	650	m		
Braking force		=	0.478154	**kN/m**		

3. Wind Force

As per IRC:6-2017 Cl. 209.3.3

Case - 1 ***Wind Speed*** ***44*** ***m/s***

1.Wind Force on Super Structure

I .Transverse wind force F_T = **$P_z*A_1*G*C_D$**

Vz	=	47.1x (44/33)	62.8	N/m^2
P_z	=	1593.6*(44/33)^2	2833.1	N/m^2
A_1	=		3.00	m^2
G	=	IRC 6 209.3.3	2	
C_D	=	IRC 6 209.3.3	1.20	
F_T	**=**	**$P_z*A_1*G*C_D$**	**20.40**	**kN/m**

II. Longitudinal wind force F_L = = 25% of Transverse wind force

F_L	**=**	**F_T X 0.25**	**=**	**5.10**	**kN/m**

20.40 KN/m of load intensity to be applied on 1 crash barrier in transverse direction.

2.55 KN/m of load intensity to be applied on both crash barriers in longitudinal direction.

III. Vertical Wind Force

F_V	**=**	**$P_z*A_3*G*C_L$**		
P_z	=	1593.6*(44/33)^2	2833.1	**N/m^2**
w	=		26	**m**
A_3	=		26	**m**
G	=	IRC 6 209.3.3	2	
CL	=	IRC 6 209.3.5	0.75	
F_V	**=**		**110.49**	**kN/m**

2.Wind Force on Substructure

Transverse wind force F_T = **$P_z*A_1*G*C_D$**

P_z	=	1593.6*(44/33)^2	2833.1	**N/m^2**
w	=	4 A1=	4.0	m
G	=	IRC 6 209.3.3	2	
C_D	=	Table 13 IRC-6: 2017	0.60	
F_T	**=**	**$P_z*A_1*G*C_D$**	**13.60**	**kN/m**
F_L	**=**	**F_T**	**13.60**	**kN/m**

Case - 1 ***Wind Speed*** ***44*** ***m/s***

1.Wind Force on Pylon

I .Transverse wind force F_T = **$P_z*A_1*G*C_D$**

Vz	=	49.1x (44/33)	65.5	N/m^2
P_z	=	1593.6*(44/33)^2	2833.1	N/m^2
A_1	=		7.00	m^2
G	=	IRC 6 209.3.3	2	
C_D	=	IRC 6 209.3.3	1.20	
F_T	**=**	**$P_z*A_1*G*C_D$**	**47.60**	**kN/m**

1.Wind Force on Cables

I .Transverse wind force F_T = **$P_z*A_1*G*C_D$**

Vz	=	49.1x (44/33)	65.5	N/m^2
P_z	=	1593.6*(44/33)^2	2833.1	N/m^2
A_1	=		0.10	m^2
G	=	IRC 6 209.3.3	2	
C_D	=	IRC 6 209.3.3	1.20	
F_T	**=**	**$P_z*A_1*G*C_D$**	**0.68**	**kN/m**

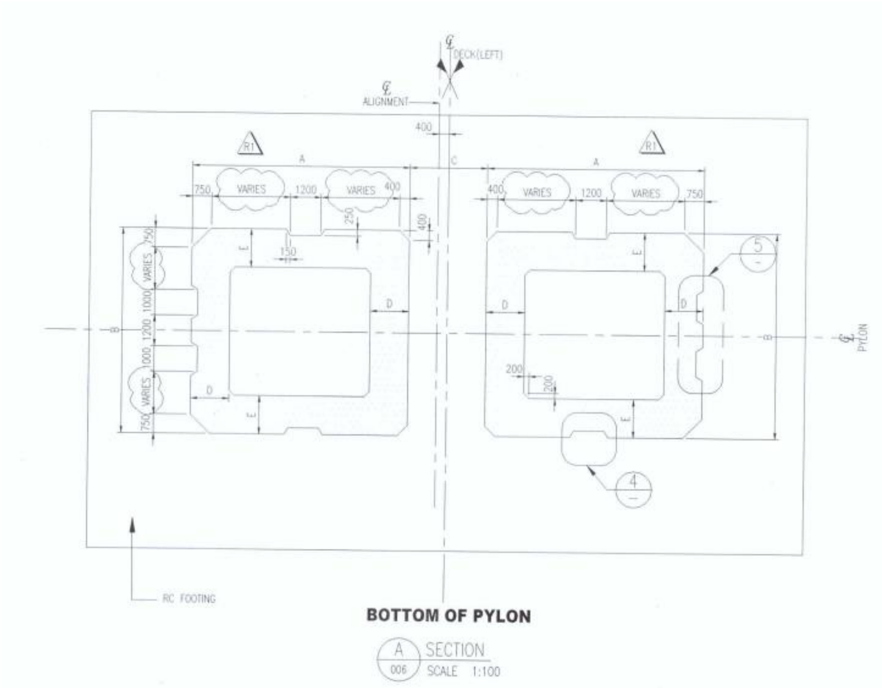
CONSTRUCTION OF PYLONS

The Pylons are constructed by the Slip form method with the piers and pylons being constructed in a **lift-wise manner**. Each lift is of 4m height and 46 such lifts are required to reach the top of the pylon. The deck which is at almost 100m height from the foundation level is constructed at the 25^{th} lift.

Almost 32 lifts have already been raised in the figure shown below.

The construction of pylons takes place through the **Automatic Climbing Formwork**. It is a three-tier arrangement to construct the structure in a lift-wise manner. This formwork is lifted with the help of tower crane and is marked in red in the figure.

A typical cross-section of the pylon is shown to the right



CONSTRUCTION OF DECK

Cantilever Form Traveller (CFT)

The deck and the superstructure are constructed using the **Balanced Cantilever Method**. The deck is casted segmentally with the help of the CFT.

The Cantilever Form Traveller consists of a large steel truss framework that is supported by a set of temporary supports or towers. It is typically positioned at one end of the bridge or viaduct and gradually extends outwards as the construction progresses. It weighs nearly 325 tonne.

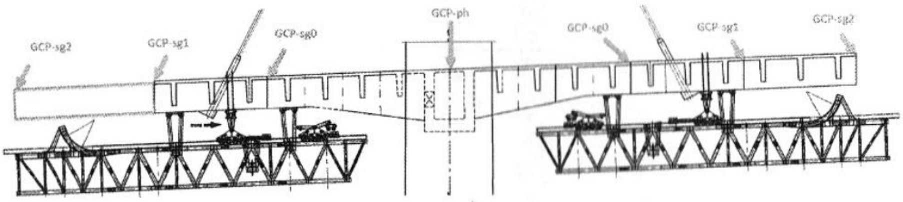
The CFT is placed at the cross beam of the pylon initially. The first segment, either precast or cast in situ, is placed on the CFT. The CFT then extends outward incrementally by pushing or pulling itself along the completed segments, allowing for the placement of subsequent segments. This process of segment placement, balanced construction, and incremental extension is repeated until the entire bridge or viaduct is completed.

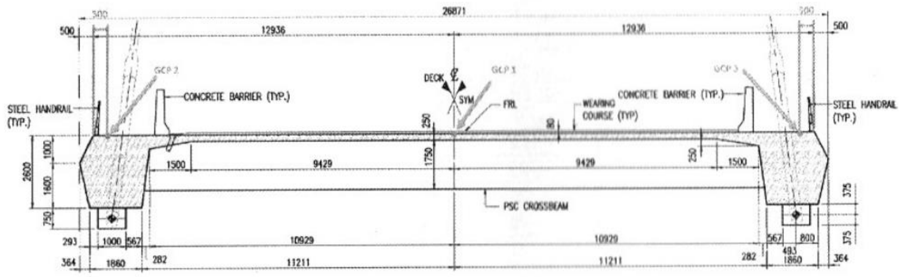
The deck is constructed simultaneously on both sides of the pylon. This helps in balancing the forces equally. As soon as one segment is casted, it is simultaneously stressed through cables that are attached to the pylon on the opposite side.

SITE VISIT

Geometry Control Point Diagrams

The purpose of the GCP is to ensure that the construction takes place at the appropriate coordinates. These are the coordinates that are surveyed using the total station and auto level. A slight variation in the alignment within the permissible limits is acceptable but major variations need to be looked at carefully.





In longitudinal direction, the GCP point is arranged at the center of pier head segment and at the front of the segment.

In transverse direction, the GCP point is arranged at the centre of section and 500mm from the edge of the edge beam.

Prestressing in cross beam of pylon

This is the **sheathing pipe** used for prestressing tendons in the cross beam.

The stay cables are guided through the **Guide Pipe** which are present in the anchor block. These guide pipes are inclined at appropriate angles and the anchor blocks are fitted in the pylon. The anchor blocks are suitably reinforced as well.

HDPE stay pipe of 200mm dia

15.7mm dia strands present in cables

CONCLUSION

Practical insights gained from a site visit significantly enhanced my understanding of various construction methodologies, particularly the balanced cantilever method used for the deck and the lifting method employed for the pylon. Observing these techniques in action provided a deeper appreciation for their complexity and precision.

The project highlighted the numerous advantages of cable-stayed bridges. These structures are particularly efficient in converting bending moments into axial forces, optimizing material usage while ensuring robust structures capable of withstanding significant loads and environmental stresses. The Mumbai-Pune Expressway Missing Link Project serves as a prime example of how modern engineering can address complex infrastructure challenges, promising improved connectivity and enhanced travel efficiency.

This internship has been instrumental in providing a profound understanding of both the theoretical and practical aspects of cable-stayed bridge construction. The comprehensive approach, which included detailed modeling, rigorous analysis, and practical site visits, has resulted in a well-rounded understanding of cable-stayed bridges. This experience has enriched my technical expertise and underscored the importance of integrating theoretical knowledge with practical application in civil engineering.