Mumbai Pune Missing Link Expressway Project

Engineering Marvel: Enhancing Connectivity and Reducing Travel Time between Mumbai and Pune

Project Authority: MSRDC
Project Contractor: Afcons Infrastructure Limited

Internship Report By:
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I understand that this report may require editing or modifications for any miscommunication, formatting, consistency, and clarity purposes, without altering the overall content and findings presented in the original document.

I declare that the internship report is the result of my original work and that any external sources used have been properly cited and acknowledged. I take full responsibility for any inaccuracies or omissions present in the report.

Date: 22th June 2024
Name: Piyush Raj Vardhan
Roll Number: 210725

INTRODUCTION

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. Approved on June 13, 2017, this project involves the construction of an 8-lane, access-controlled highway designed to bypass the treacherous Khandala Ghat, notorious for its hairpin turns and frequent landslides.

Project Highlights:

- **Total Length:** 13.3 km
- **Connectivity:** Khopoli to Kusgaon
- **Travel Time Reduction:** 25 minutes
- **Distance Reduction:** 6 km
- **Key Structures:** Two twin tunnels (1.75 km and 8.92 km), one cable stayed bridge (650 m), three major bridges, one minor bridge, multiple culverts (11 pipe culverts and two box culverts)
- **Bridge Features:** 650m cable-stayed bridge with 180m tall pylons, decks approximately 100m above the ground

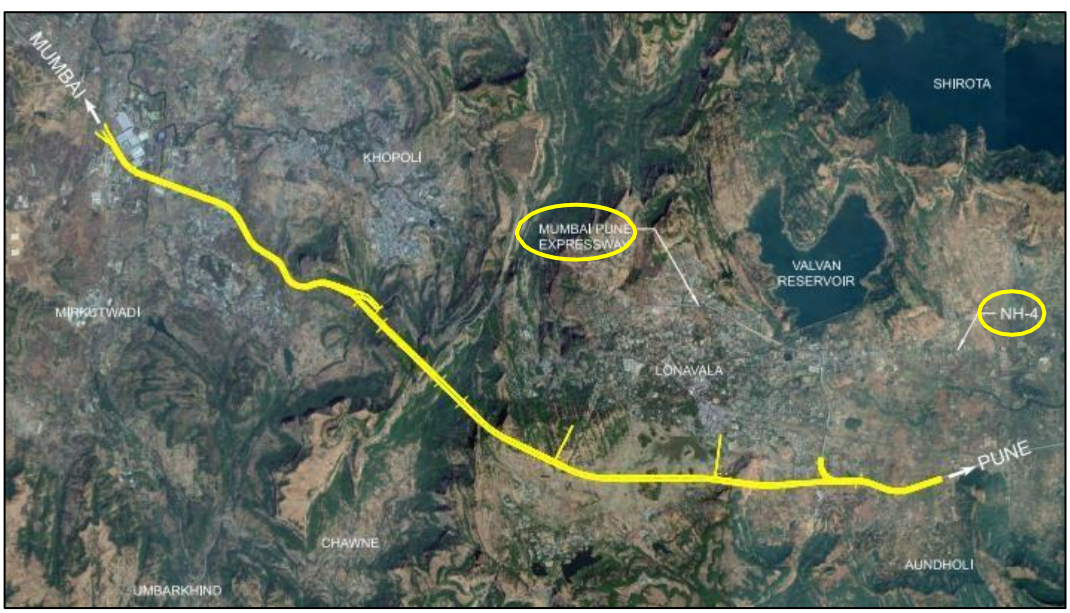


FIGURE 1 SATELLITE MAP OF OVERALL PROJECT SCOPE

The expressway currently experiences severe congestion, particularly in the section from **Adoshi** Tunnel to **Khandala** exit, where the **traffic** of the 6-lane Mumbai-Pune Expressway and the 4-lane NH-4 merges. This bottleneck, coupled with frequent **landslides**, significantly hampers travel speed and safety, prompting the need for this project. The new alignment is expected to alleviate these issues, providing a more direct and safer route.

Environmental and technical clearances for the project were secured, including the State Environmental Impact Access Authority (**SEIAA**) approval on August 24, 2018. The project is divided into two packages: Package-I involves the construction of the tunnels, and Package-II involves the construction of the viaducts and the upgradation of the expressway from 6 to 8 lanes between Khalapur Toll Plaza and Khopoli Exit.

The project is being executed on an Engineering, Procurement, and Construction (EPC) mode, with Afcons Infrastructure Limited awarded the contract for **Package-II**. The total estimated cost of the project is Rs. 1491Crores with GST, and it is slated for completion by March 2025. This ambitious project not only aims to enhance travel efficiency but also to significantly reduce the number of accidents and improve overall road safety on this vital expressway corridor.

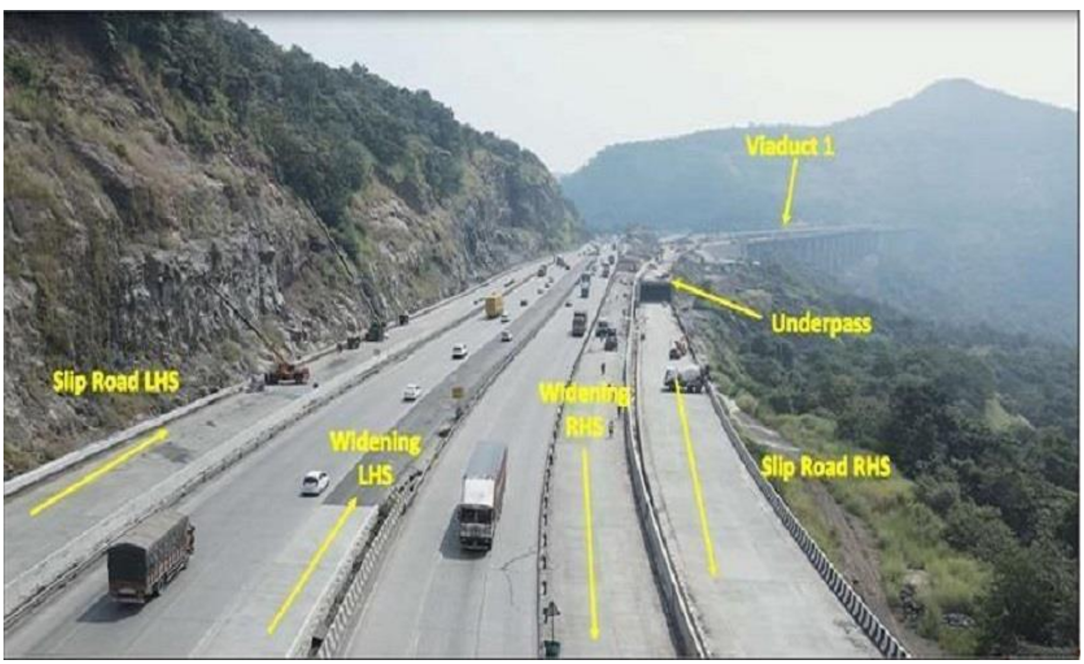


FIGURE 2: ILLUSTRATION SHOWING WORKS DONE UNDER PROJECT

PROJECT SCOPE

The scope of work for Package II includes capacity augmentation from the Khalapur Toll Plaza to the Khopoli Exit, project involves the widening of the expressway from 6 lanes to 8 lanes between km 32/800 to km 38/660, covering a distance of 5.86 km. This section involves the enhancement of three major bridges, one minor bridge, one Vehicular Under Pass (VUP), and two Passenger Under Passes (PUP), summing up to a total road development length of approximately 7.6 km. Additionally, a new approach road of 2.1 km has been constructed to access the construction site.

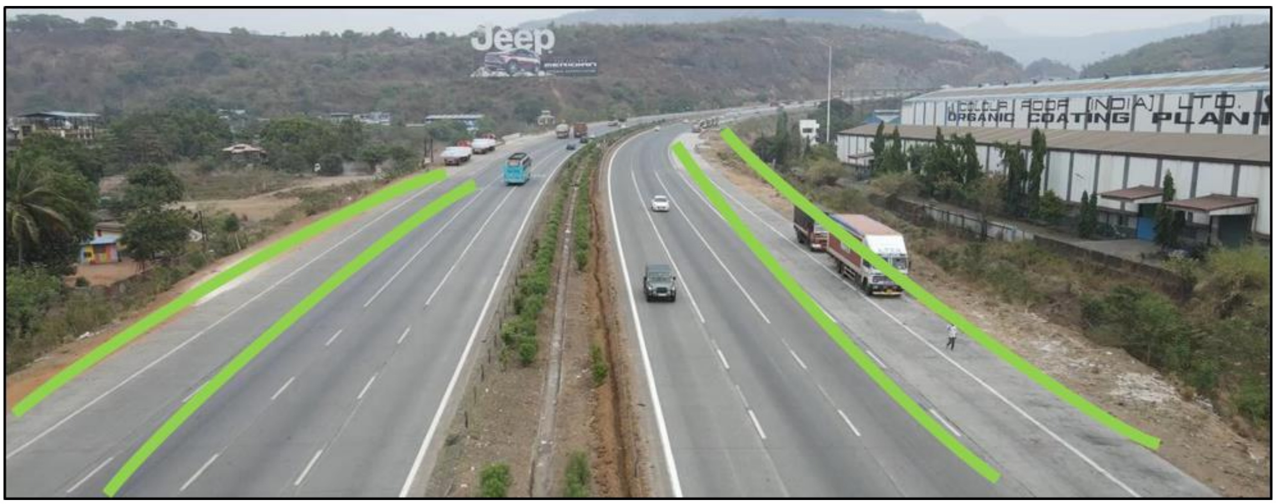


FIGURE 3: THE CAPACITY AUGMENTATION HAS BEEN COMPLETED AND MARKED IN GREEN SHOWS THE ADDITIONAL LANE WITH PAVED AND EARTHEN SHOULDERS ON BOTH SIDES.

FIGURE 4: 13.8M WIDE VUP1 CONNECTING CHICHAWALI VILLAGE

This package includes Viaduct 1, which is a bridge with slip roads on both sides, consisting of 20 spans on the left-hand side and 28 spans on the right-hand side, with a total length of 850 meters ; each span 30 m long.

FIGURE 5A: DRONE SHOT OF VIADUCT 1 AFTER BEING COMPLETED

FIGURE 5B: ANOTHER ANGLE OF VIADUCT 1

A significant feature of this package is **Viaduct 2**, a cable-stayed bridge with a total span of 650 meters. This bridge is supported with 8 piers ranging in height from 50-70 m and 4 pylons of height 170-180 m.

Pylons: P3L, P3R, P4L, P4R

Piers: P1L, P1R, P2L, P2R, P5L, P5R, P6L, P6R

Distance of span between P1 to P2 and P5 to P6 = 40 m

Distance of span between P2 to P3 and P4 to P5 = 132.5 m

Distance of main span between P3 to P4 = 305 m

FIGURE 6: VIEW OF MUMBAI SIDE VIADUCT 2 CAPTURED FROM CENTERLINE

The enhancements in Package II are designed to address current bottlenecks and improve overall traffic flow and safety on the Mumbai-Pune Expressway. The cable-stayed bridge at Viaduct 2, with its significant height and span, is a key feature aimed at providing a more direct and safer route, bypassing the hazardous sections of the expressway.

FIGURE 7: PICTURE SHOWING TWO PYLONS P4L (LEFT) AND P4R (RIGHT) WITH PIERS AT BACK, ALSO HIGHLIGHTING THE TWO TUNNELS

FIGURE 8A: DRONE SHOT SHOWING THE PUNE SIDE V2; PIERS P5L AND P5R PAINTED WITH ANTI CARBONATION PAINT; ALSO SHOWING THE APPROACH ROAD WHICH GOES THROUGH AUDIT

FIGURE 8B: P1 TO P2 DECK SLAB COMPLETED (LEFT) AND WORK IS GOING ON PIER P2

DEPARTMENTS

1) Batching Plant:

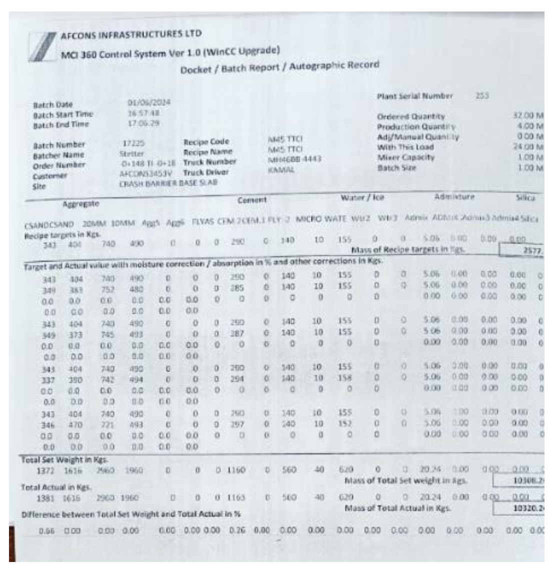
The batching plant plays a critical role in the concrete production process, ensuring the delivery of high-quality and consistent concrete for the construction project. The batching plant equipment typically consists of a weigh hopper, overhead bins, and a mixer. The **weigh hopper**, which is loaded from overhead bins by gravity, discharges materials onto a conveyor belt leading to the mixer. Cementitious materials are weighed independently of aggregates using separate scales or compartments to ensure accuracy.

The charging and discharging gates of the weigh hopper must operate with precise interlocks to maintain the integrity of the concrete mix. Cement weigh hoppers are equipped with access ports for inspection, coned bottoms, and **vibrators** to ensure complete discharge of materials.

FIGURE 9: A TRIMIXER IN BATCHING PLANT

Before mixing, the mixer is thoroughly inspected to comply with specifications regarding blade wear, drum speed, and timing. Mixers with capacities of 0.3 m³ or more are equipped with **automatic** timers to ensure the proper mixing period. The mixing cycle time typically lasts around 75 seconds with total cycle time of around **7-8 minutes**.

The batching plant is generally referred to as **M1**, which implies that 60 m³ concrete is produced in 1 hour time period. Trimixers are fixed in the plant which operate one by one. Material enters in the plant through 4 different gates and 4 load cells each 100kg.



AFCONS INFRASTRUCTURES LTD
MCI 360 Control System Ver 1.0 (WinCC Upgrade)
Docket / Batch Report / Autographic Record

Batch Date 01/06/2024
Batch Start Time 16:57:48
Batch End Time 17:06:29
Batch Number 17225
Batcher Name Stetter
Order Number 0+148 TI 0+18
Customer AFCONS3453V
Site CRASH BARRIER BASE SLAB
Recipe Code M45 TTCI
Recipe Name M45 TTCI
Truck Number MH46BB 4443
Truck Driver KAMAL
Plant Serial Number 253
Ordered Quantity 32.00 M
Production Quantity 4.00 M
Adj/Manual Quantity 0.00 M
With This Load 24.00 M
Mixer Capacity 1.00 M
Batch Size 1.00 M

Aggregate / Cement / Water / Ice / Admixture / Silica

CSAND	CSAND	20MM	10MM	Agg5	Agg6	FLYAS	CEM	2CEM.1	FLY-2	MICRO	WATE	Wtr2	Wtr3	Admix	ADMIX	Admix3	Admix4	Silica
Recipe targets in Kgs.																		
343	404	740	490	0	0	0	290	0	140	10	155	0	0	5.06	0.00	0.00	0.00	
Target and Actual value with moisture correction / absorption in % and other corrections in Kgs.																		
343	404	740	490	0	0	0	290	0	140	10	155	0	0	5.06	0.00	0.00	0.00	0
349	383	752	480	0	0	0	285	0	140	10	155	0	0	5.06	0.00	0.00	0.00	0
0.0	0.0	0.0	0.0	0.0	0.0	0	0	0	0	0	0	0		0.00	0.00	0.00	0.00	0
0.0	0.0	0.0	0.0	0.0	0.0													
343	404	740	490	0	0	0	290	0	140	10	155	0	0	5.06	0.00	0.00	0.00	0
349	373	745	493	0	0	0	287	0	140	10	155	0	0	5.06	0.00	0.00	0.00	0
0.0	0.0	0.0	0.0	0.0	0.0	0	0	0	0	0	0	0		0.00	0.00	0.00	0.00	0
0.0	0.0	0.0	0.0	0.0	0.0													
343	404	740	490	0	0	0	290	0	140	10	155	0	0	5.06	0.00	0.00	0.00	0
337	390	742	494	0	0	0	294	0	140	10	158	0	0	5.06	0.00	0.00	0.00	0
0.0	0.0	0.0	0.0	0.0	0.0	0	0	0	0	0	0	0		0.00	0.00	0.00	0.00	0
0.0	0.0	0.0	0.0	0.0	0.0													
343	404	740	490	0	0	0	290	0	140	10	155	0	0	5.06	0.00	0.00	0.00	0
346	470	721	493	0	0	0	297	0	140	10	152	0	0	5.06	0.00	0.00	0.00	0
0.0	0.0	0.0	0.0	0.0	0.0	0	0	0	0	0	0	0		0.00	0.00	0.00	0.00	0
0.0	0.0	0.0	0.0	0.0	0.0													
Total Set Weight in Kgs.																		
1372	1616	2960	1960	0	0	0	1160	0	560	40	620	0	0	20.24	0.00	0.00	0.00	
Total Actual in Kgs.																		
1381	1616	2960	1960	0	0	0	1163	0	560	40	620	0	0	20.24	0.00	0.00	0.00	
Difference between Total Set Weight and Total Actual in %																		
0.66	0.00	0.00	0.00	0.00	0.00	0.00	0.26	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Mass of Recipe targets in Kgs. 2577.
Mass of Total Set weight in Kgs. 10308.2
Mass of Total Actual in Kgs. 10320.2

FIGURE 10: REPORT OF CONCRETE PRODUCTION AFTER 1 CYCLE

Report showing the materials used and wasted in one complete cycle. The quantities are measured accurately upto 100 grams.

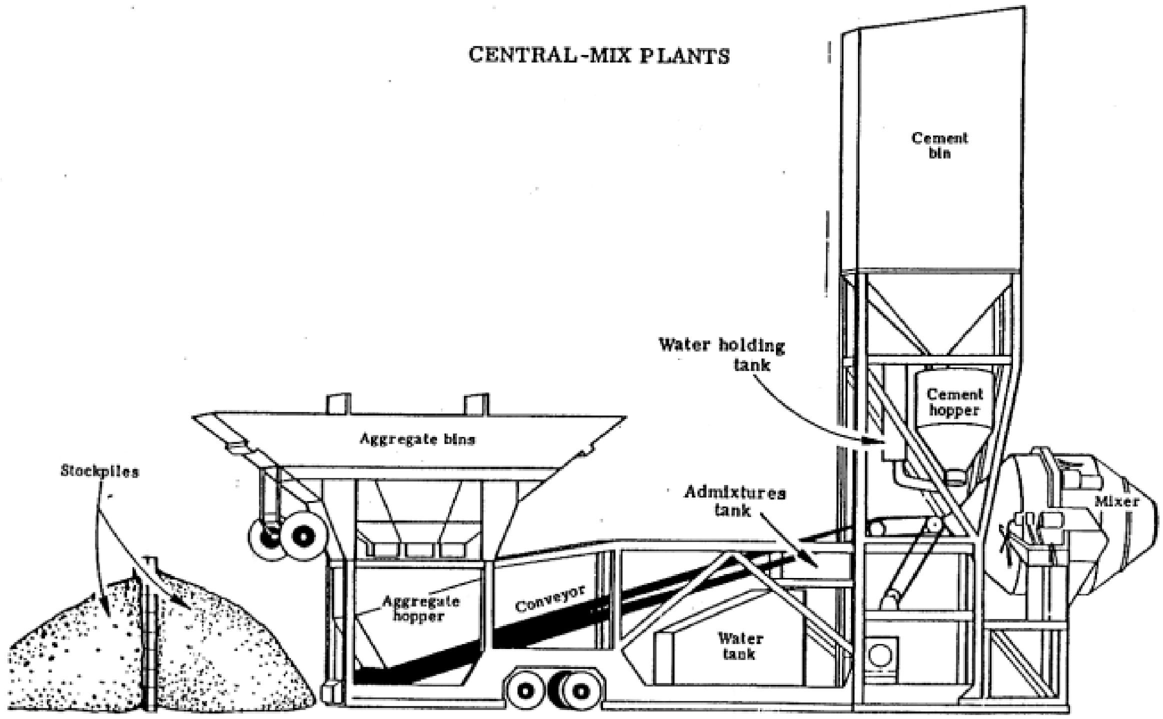


FIGURE 11: SCHEMATIC DIAGRAM OF THE BATCHING PLANT SHOWING ALL THE NECESSARY EQUIPMENTS

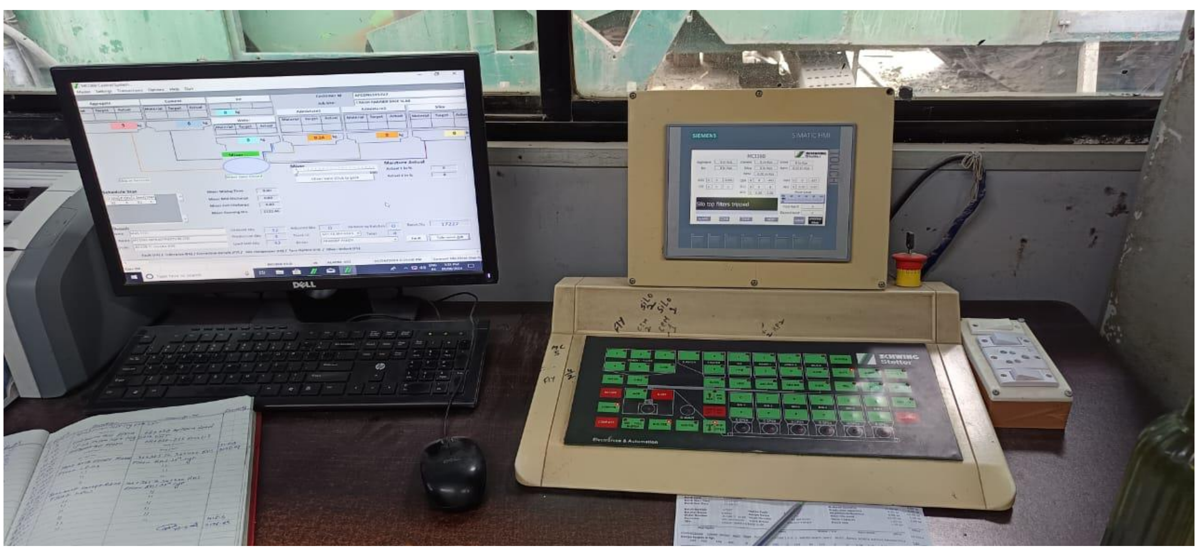


FIGURE 12: CONTROL SYSTEM FOR AUTOMATIC AND MANUAL OERATION OF BATCHING CYCLE

The above system has a pre fixed quantities proportion to be used for production of a particular grade concrete. It illustrates the different amounts of materials viz. aggregates, fly ash, admixtures, water, cement, etc. used.

2) Quality Assurance and Quality Control (QAQC):

The department dedicated to ensuring quality focuses on both assurance and control aspects, encompassing material procurement (sourcing), testing, mixing in the correct proportions, and recording all engineering aspects of the materials for approval.

For flexural testing of concrete, first water curing is done for 28 days in an accelerated curing tank (**ACS**) and then it is placed under load at center and the load reading against the failure of the block is recorded.

FIGURE 13: ACS TANK USED FOR CURING CONCRETRE BLOCK FOR 28 DAYS

Several tests including Loss of Ignition (LOI) at 975°C, elongation, flakylation, lime reactivity test and also the setting time (30 minutes) and consistency (5-7 mm) tests of cement.

A concrete which satisfies specific requirements as per required conditions is called high performance concrete (**HPC**). For a cement design, it is **mix behaviour** (workability, transportation, setting time) which is way more important than mix strength.

Soil testing is critical as the entire structure relies on it. QA tests are conducted with a geotechnical engineer, including Grain Size Analysis (both wet and dry), Maximum Dry Density (MDD), Optimum Moisture Content (OMC), Atterberg limits, Casagrande method, and Soil Bearing Capacity (SBC).

FIGURE 14: LOSS OF IGNITION (LOI) EUIPMENT FOR TESTING OF CEMENT

3) Health Safety and Environment (HSE):

Ensuring a safe and healthy work environment is a top priority. This department focuses on comprehensive safety measures and fostering a supportive atmosphere.

Daily Instructions and Work Allotment

Workers receive instructions in their mother tongue, fostering a sense of well-being and creating a supportive work environment. This practice, conducted almost daily, enhances understanding of assigned tasks and ensures planned work is executed efficiently. It also strengthens team bonding between workers and support staff.

Safety Gear and Identification

Distinct variations in helmets and jackets help identify roles:

- **Jackets:** Engineers, supervisors, and foremen wear green; workers wear orange; and drivers wear dark blue.
- **Helmets:** Workers are assigned yellow helmets, site engineers wear white, and safety in-charges don green helmets.

Any individual found on-site without a helmet, jacket, safety shoes, or a safety harness (when working at heights) is immediately asked to leave. They are then counseled and penalized for the first offense. Repeated offenses result in debarment from the site.

Safety Induction and Compliance

All employees must undergo a safety induction, complete proper documentation, receive a general doctor's verification, and obtain a **PPE** (Personal Protective Equipment) kit. Regular attendance ensures proper employee management, maintenance of records, and adequate work allotment, followed by government-approved daily wages as per Section 81 (1) of the Labour (R&A) Act 1970.

FIGURE 15: AN ENGINEER GIVING INSTRUCTIONS ON SAFETY INDUCTION

CONSTRUCTION OF PYLON

In our scope, there are four pylons and eight piers to be constructed. Each pylon is made with open foundation at base except one i.e., **P3L** which is made with pile foundation. It consists of **42** piles of diameter 1.5 m casted 28 m deep into ground.

The pylons and piers are constructed in a lift-wise manner. Each **lift** is a 4m high concrete block which are continuously made joining lower lift to the upper. For e.g., around 46 lifts are required to construct P3R upto its top height.

The two legs of each pylon are diverted from the foundation with outer wall angle 86.4° and inner wall angle 83.9° running upwards to reduce the size of cross section as seen from top. Each leg is designed to be a hollow column-like structure.

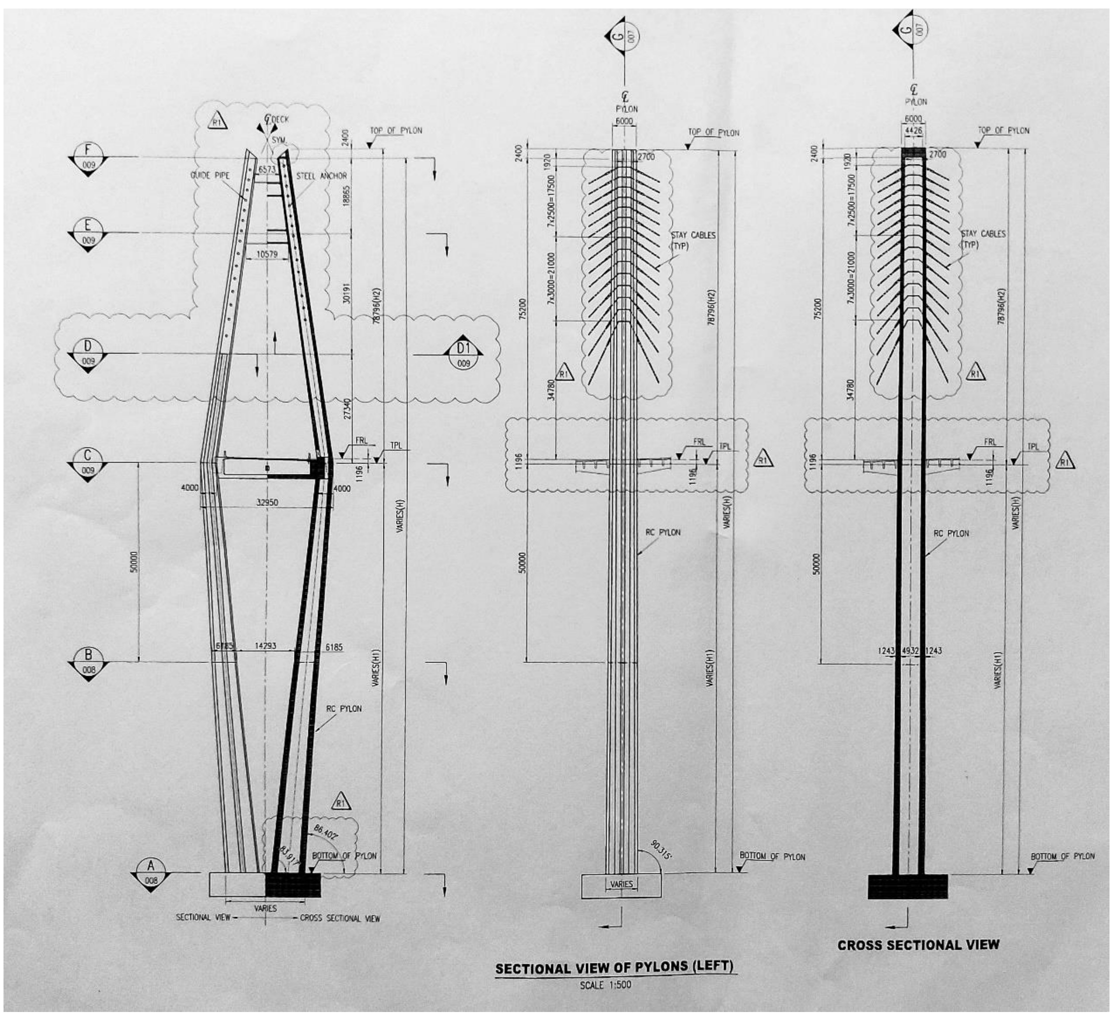


FIGURE 16: SECTIONAL VIEW OF PYLONS (LEFT)

A crossbeam is constructed at a height of approx. 100m from the foundation on which a deck is to be made on top the crossbeam. Post tensioning of these crossbeams is done to reduce the material which leads to saving overall cost and providing stability to superstructure. M70 grade concrete is used in making deck and crossbeams while M60 concrete is used in pylon legs.

For each pylon, an arrangement for 15 stay cables is made with steel anchor boxes fitted at equal spacing as shown in figure.

Reinforcement

Reinforcement with 32Φ vertical bars and 16Φ horizontal bars is done with spacing 200mm along with anchorage bars. The vertical bars are **threaded** on both ends to interconnect the lower and upper lifts. A cap made of plastic is put on each of these threaded portions while concreting so not to lose the grip (if covered with concrete accidentally).

Fe500 HYSD bars having minimum elongation 16% were used in reinforcement. A minimum clear cover of 75mm below turning point level (TPL) and 40mm above TPL.

FIGURE 17: PHOTO SHOWING VERTICAL BARS AT P4R COVERED WITH PLASTIC BAR CAPS TO PREVENT FILLING OF END THREADS DURING CONCRETING

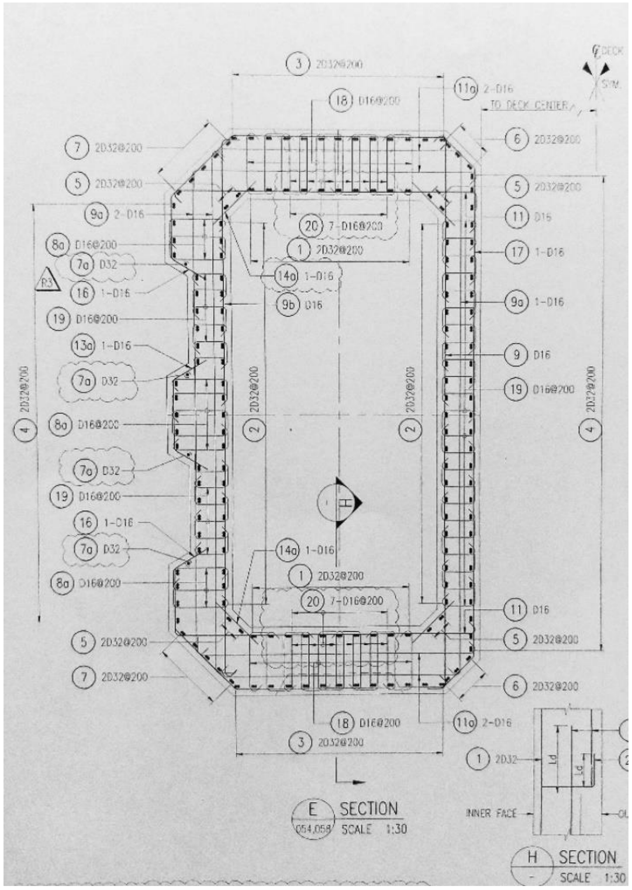
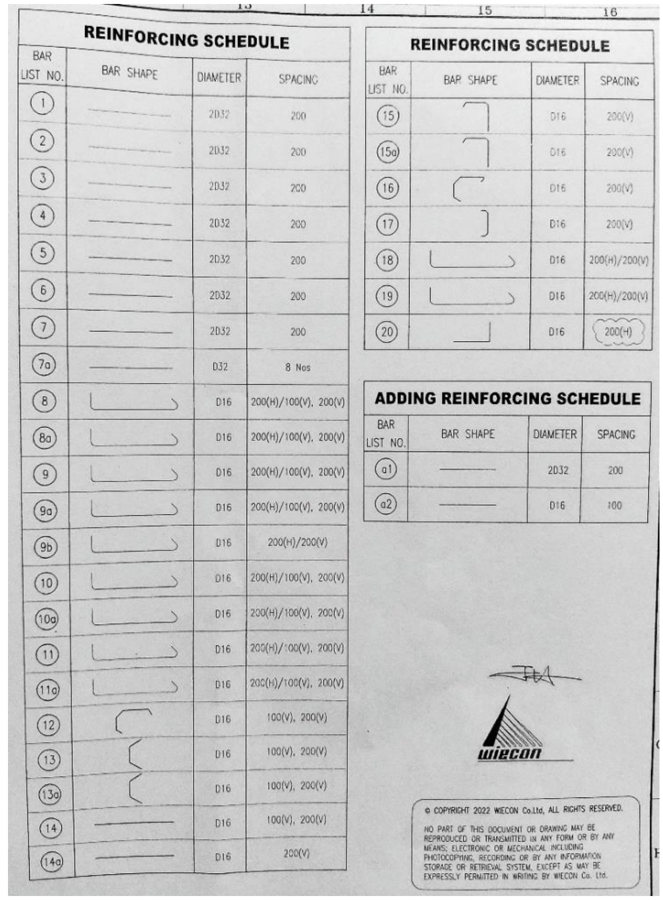


Figure 18: Reinforcement arrangement for E section of pylon w.r.t. Figure 16; the type of steel bars to be attached is also shown with referential numbering



REINFORCING SCHEDULE

BAR LIST NO.	BAR SHAPE	DIAMETER	SPACING
1		2D32	200
2		2D32	200
3		2D32	200
4		2D32	200
5		2D32	200
6		2D32	200
7		2D32	200
7a		D32	8 Nos
8		D16	200(H)/100(V), 200(V)
8a		D16	200(H)/100(V), 200(V)
9		D16	200(H)/100(V), 200(V)
9a		D16	200(H)/100(V), 200(V)
9b		D16	200(H)/200(V)
10		D16	200(H)/100(V), 200(V)
10a		D16	200(H)/100(V), 200(V)
11		D16	200(H)/100(V), 200(V)
11a		D16	200(H)/100(V), 200(V)
12		D16	100(V), 200(V)
13		D16	100(V), 200(V)
13a		D16	100(V), 200(V)
14		D16	100(V), 200(V)
14a		D16	200(V)

REINFORCING SCHEDULE

BAR LIST NO.	BAR SHAPE	DIAMETER	SPACING
15		D16	200(V)
15a		D16	200(V)
16		D16	200(V)
17		D16	200(V)
18		D16	200(H)/200(V)
19		D16	200(H)/200(V)
20		D16	200(H)

ADDING REINFORCING SCHEDULE

BAR LIST NO.	BAR SHAPE	DIAMETER	SPACING
a1		2D32	200
a2		D16	100

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Figure 19: Reinforcing Schedule for the Figure 18; it shows how different types of bars must be placed in the reinforcement with accurate designation

Automatic Climbing Formwork (DOKA)

For constructing pylons, automatic climbing formwork is used. It is a mechanism by which we climb up the pylon legs to construct the structure in a lift wise manner. It is a three tier arrangement supported by steel girders, spindles and hydraulic jacks. An important jointing element is **guiding shoe** along with climbing cone. But a manual system called '**crane jumping formwork**' was used in construction in piers in which the whole arrangement is lifted up by tower crane.

FIGURE 20: DOKA SYSTEM FOR PYLON LEG AT P4R

Spindles are fastened and welded to each of the three horizontal tiers. A pulley system with steel chain is attached to fence of the tier to adjust the arrangement with ease as wherever required. Also, turnbuckles are provided as only shutters can't provide the necessary strength to the arrangement.

Cantilever form traveller (CFT) is a method which is used for deck and segment construction. An arrangement of CFT includes 6 hydraulic jacks which lift the whole arrangement upto the desired height and screw jacks which support the load of whole arrangement. Pins are inserted for establishment of jacks. A strong foundation is needed to assemble such a heavy steel truss arrangement and thus a foundation is created just aside the pylons with steel columns to carry the whole weight of arrangement.

FIGURE 21: CFT ARRANGEMENT READY FOR UPLIFTING HIGHLIGHTING YELLOW HYDRAULIC JACKS

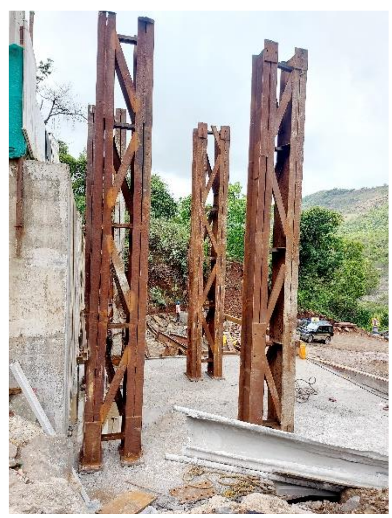

FIGURE 21B: STRONG FOUNDATION ASIDE WITH STEEL COLUMNS AT P4R FOR CFT

CONCRETING

There are two ways to do concreting viz., crane & bucket system and pipe system. The pipe system is used in concreting of the deck and crossbeam because:

- It requires a large amount of volume to be concreted
- the large volume will require more time to complete the process
- piping provides a continuous flow of concrete which save time

While bucket concreting is used in pylons (legs) as it requires lesser volume (~ 50-70 m^3) than deck and can be completed in a day.

Note:- Pipe concreting is **not** preferred here for pylon legs because the volume required at pylon legs is low and reduce with height.

We will describe the procedure used at P4R for concreting of pylon leg (right as seen from Mumbai end) at section D. The volume of concrete required is 58 m^3.

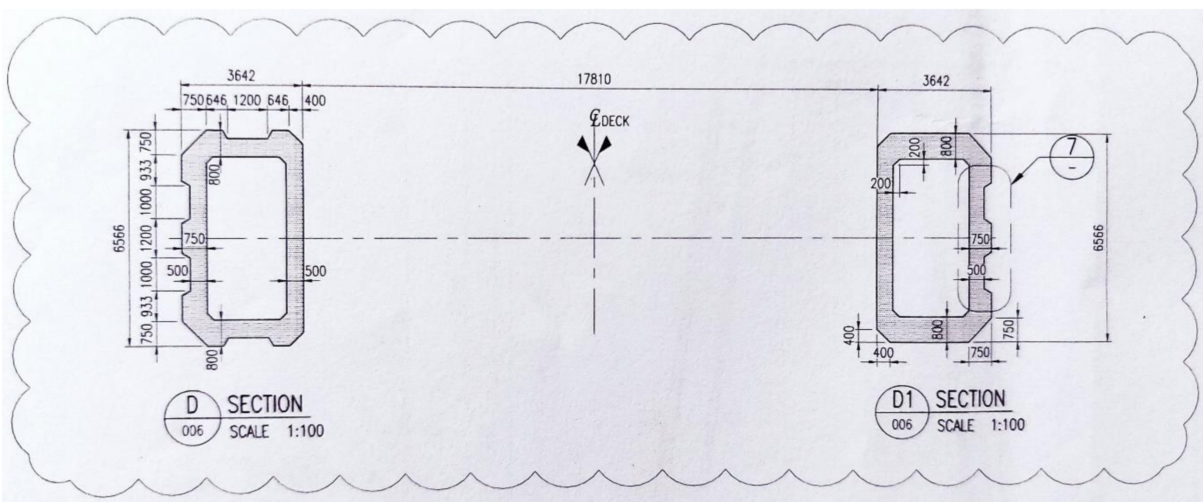

FIGURE 22: CROSS SECTION OF PYLON P4R TO BE CONCRETED

Procedure

After doing the necessary activities of DOKA system and reinforcement we move to the final stage of lift construction; concreting. This is based on bucket system.

1) A concrete mixer truck with specific assigned number comes at the site location from batching plant. It has concrete which is to be moved

continuously otherwise the concrete may set in the mixer and it will be waste because **M60** concrete is quickly settable and very strong.

2) It is the duty of the quality engineer to check the properties of concrete in transit mixer viz., **workability** must be around 3 hours (keeping in mind the transportation time) and minimum settling time (4 hours). **Temperature** of concrete is also measured and if it is higher than permissible (30°C) then ice is mixed in water that is used in concrete to lower its temperature in a tank.
3) A bucket as shown in figure is filled with concrete on the ground itself from the transit mixer. It has a capacity of **3 m³**.
4) The bucket is attached to crane wire rope having a capacity of 20 ton and then brought to the height required (110 m). It takes around 5 minutes to **bring the bucket** from ground to top.
5) An operator controls the opening of bucket using hydraulic jack system attached to it through controller as required. It takes around 4 minutes to empty the bucket.
6) After pouring concrete, the concrete is **compacted** with **needle vibrators** operated till air voids are not visible. Then concrete is allowed to set. Bringing bucket top to bottom take 5 minutes and further 5 minutes for filling it.

FIGURE 23: FOOTAGE SHOWING BUCKET CONCRETING BEING DONE AT P4R; THE BUCKET IS HELD BY CRANE

Total time to complete 1 cycle = 5 + 4 + 5 + 5

≈ 19 minutes

No. of times (cycles) to perform concreting of 1 lift = $\frac{58m^3}{3m^3}$ = 19.33 ≈ 20

Total time to complete 1 lift = 20 * 19 = 380 minutes

≈ 7 hours

After the setting of concrete, survey is done on the edges and corners of the casted concrete pylon to ensure their coordinates are well within the permissible limits.

Cost Analysis

Since it takes almost 7 hours to complete the work, we can consider it as one full day and thus we will estimate the cost per day wherever possible.

For concreting, 8 workers were hired on daily basis and 1 engineer with 1 supervisor were present at the site. Further, a crane (20 ton) and bucket system was used, and three transit mixers (capacity = $4m^3$, avg. speed ≈ 20 kmph) were utilised for transportation.

M60 Concrete production price = Rs 8000/cum

Cost of concrete required = 58 * 8000 = Rs 464000

Cost of Crane and bucket sytem = 15000/day

Cost of 1 transit mixer = Rs 5000/day

Cost of 3 transit mixers = 3 * 5000 = Rs 15000

Cost of 1 worker per day = Rs 800

Cost of 8 workers = 8 * 800 = Rs 6400

Cost of 1 engineer/supervisor = Rs 1500

Cost of engineer + supervisor = 2 * 1500 = Rs 3000

Total cost of concreting = 464000 + 15000 + 15000 + 6400 + 3000

= **Rs 503400**

Time Cycle for Truck

No. of cycles completed in 1 transportation = $\frac{Volume\ of\ mixer}{Voulme\ of\ bucket} = \frac{4m^3}{3m^3}$ = 1.33

No. of times the mixer has to transport = 29/1.33 =21.6 ≈ 21 cycles
Time taken in 1 transportation cycle (+ concreting time) = 0.5 + 0.3 * 2 + 0.5 = 1.6 hours
No. of cycle in 11 effective working hours = 11/1.6 ≈ 7 cycles

Thus, at least **three** transit mixers are utilized in this activity and we will complete it with three mixers very well subject to flexibility of volume of concrete required (less) and time management.

CONSTRUCTION OF CROSS BEAM

A crossbeam is the main horizontal support of a structure which supports smaller beams for highway construction. It is constructed at the height of turning point level (TPL) of the pylon, which is around 100 m from the foundation level for pylons. The construction involves making a hollow cross beam with a 250mm depth deck at top, which is shown in figure 26 at cross section C.

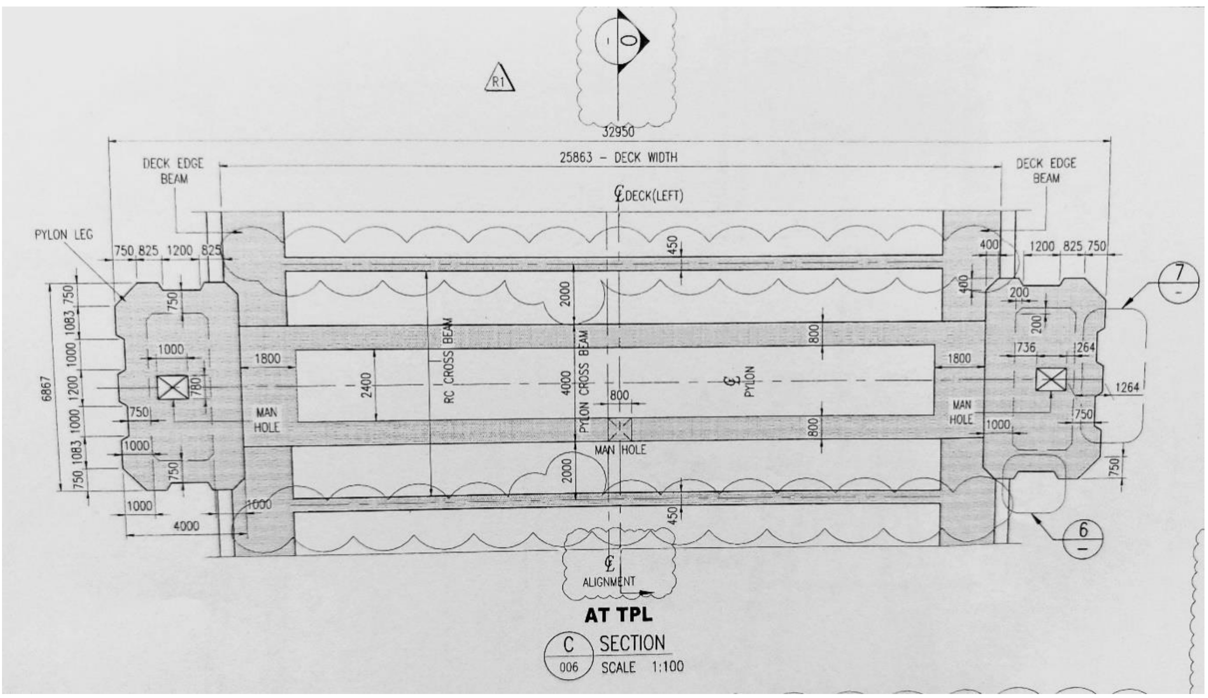

FIGURE 24: CROSS SECTION OF CROSS BEAM OF PYLON AS SEEN FROM THE PLAN VIEW

The cross beam as shown in figure 25 is 5 meter in depth such that the bottom of cross beam is a solid slab of 1 m height and then 800 mm wide walls are constructed with further elongation of 4 meters on which the deck construction will take place. HDPE corrugated pipes are installed as per design in the base slab before concreting for stressing the cross beam on both legs of pylon, which also improves the stability of pylon because it can hold pylon legs firmly at one place.

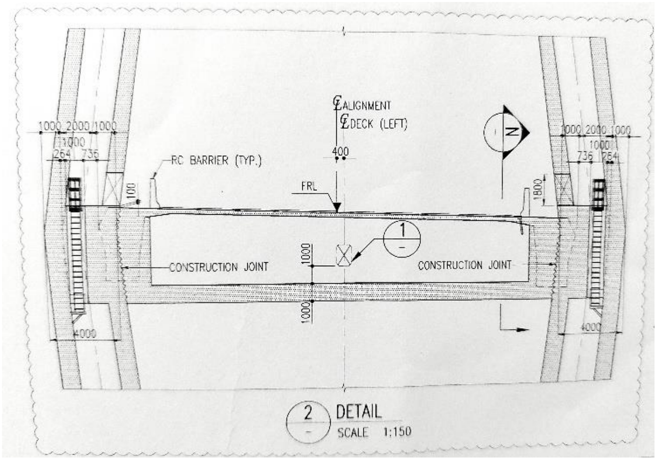

FIGURE 25: FRONT VIEW OF OF THE CROSS BEAM WITH DECK VISIBLE AT TOP

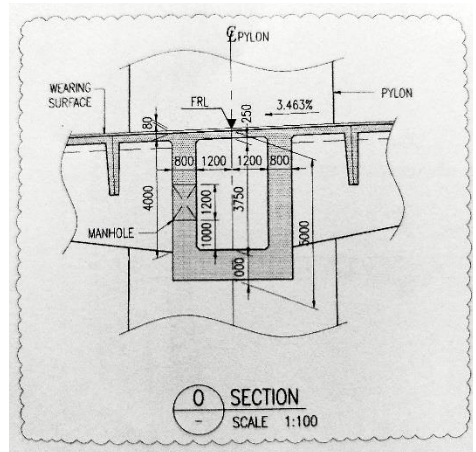

FIGURE 26: SIDE VIEW OF CROSS BEAM AT PYLON WITH SUPPORTING BEAMS AND HIGHWAY DECK GIVING A GLIMPSE OF SLOPE 3.3%

The construction of cross beam first involves the making of a support system which is made of steel beams. There are 4 screw jacks of capacity 300 ton each which are provided on each corner at TPL on the steel bracket to support all the weight and move the jacks to facilitate accurate horizontal and vertical levels. It takes about 1 month to make the supporting arrangements. MS pipes of dia 6cm are provided in pylon legs so that after concrete setting steel brackets may be fitted with bolts to hold the grip tighter because bolt threads grip the plastic and hence provide strength for support.

Pipe concreting is preferred for cross beam because it requires a large amount of concrete volume which is required continuously and uniformly. It can provide a rate of 18-20 m^3/hr with pipes of diameter 12 cm.

TMT (Thermo-Mechanical Treated) bars are used and preferred over steel and iron for reinforcement. Here, TMT 500D are used which implies that the tensile strength of this rod is 500MPa. A **coupler** is used to join two steel bars through their threaded ends.

FIGURE 27: SCREW JACK OF CAPACITY 300 TON PLACED AT ONE OF THE CORNERS UNDER CROSS BEAM CONSTRUCTION

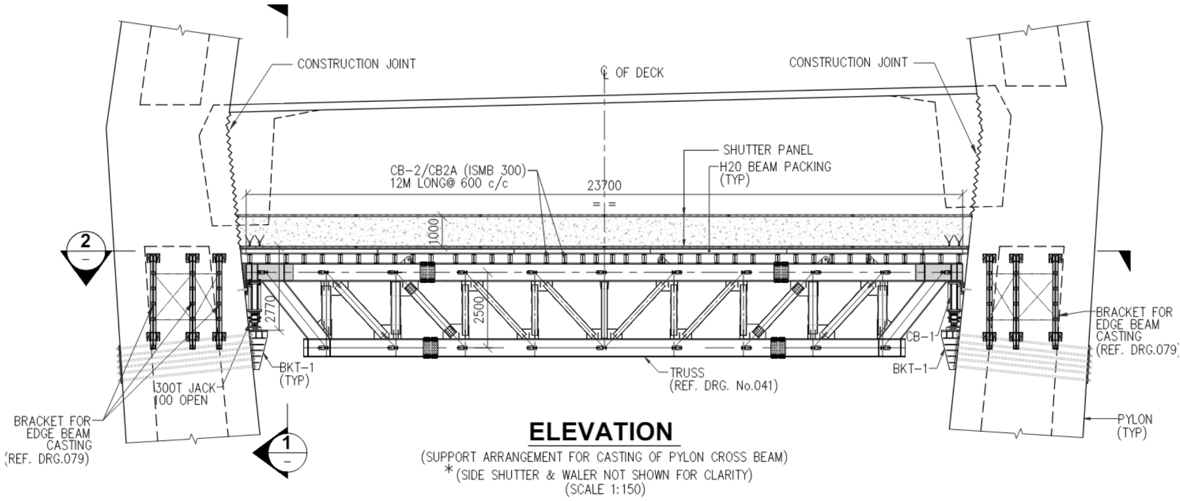

FIGURE 28: LONGITUDINAL SECTIONAL VIEW OF CROSS BEAM WITH STEEL BEAMS AS SUPPORTING STRUCTURE AND STEEL BRACKETS ARE FASTENED WITH BOLTS ACROSS THE PYLON LEG

FIGURE 29: A PIER LEG COVERED WITH ANTI CARBONATION PAINT AFTER BEING FULLY CASTED BY CONCRETING; SEVERAL HOLES ARE VISIBLE IN WHICH THE PINS WILL BE PLACE TO SUPPORT THE DECK

FIGURE 30: PIPE CONNECTION (YELLOW) ON RIGHT LEG OF PYLON P3R USED FOR PIPE CONCRETING; CROSS BEAM CONSTRUCTION IS ALSO VISIBLE AT TPL

POST TENSIONING

Post-tensioning is a special form of prestressed concrete in which the prestressing tendons are stressed after the concrete is cast. Post-tensioning utilizes high quality high strength steel such that 1 kg of post-tensioning strand may replace 3 or 4 kg of ordinary non-prestressed reinforcement. This can reduce congestion in members. Post-tensioning tendons are usually anchored with some form of mechanical anchorage device which provides a clearly defined anchorage for the tendon.

This method significantly enhances the strength and durability of concrete structures. It is particularly beneficial for large-scale projects such as bridges, where it helps in controlling deflections, reducing cracking, and balancing loads.

In Viaduct 2, post-tensioning involves several critical steps:

1. **Placement of Tendons**: During the reinforcement phase, high-strength steel tendons are placed in designated ducts within the concrete elements. These ducts are referred to as Post-Tensioning Ducts (PT ducts).
2. **Casting and Hardening of Concrete**: Concrete is then poured around the tendons and allowed to harden.
3. **Stressing of Tendons**: After the concrete has hardened, tension is applied to the tendons using **hydraulic jacks**. This process involves the following components:
    - **Anchor Head**: Secures the tendons at the ends.
    - **Wedges**: Hold the tendons in place within the anchor head.
    - **Limiting Plate**: Ensures proper alignment and force distribution.
    - **Stressing Jack/Hydraulic Pump**: Applies the necessary tension to the tendons.
    - **Grip Anchor Heads and Wedges**: Secure the tendons post-tensioning.

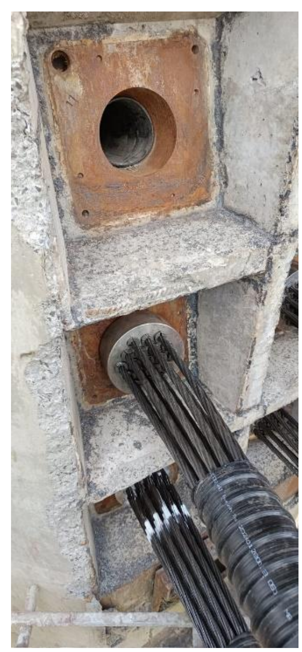

FIGURE 31: POST TENSIONED STRANDS OF A TENDON (BOTTOM)

FIGURE 32: POST TENSIONING DUCTS IN THE CROSS BEAM OF PYLON P4R

Materials and Specifications

The tendons used in this bridge are composed of 19 strands each (1 extra tendon if any other strand breaks during stressing), with a total tendon diameter of about 10 cm. Specifically, in the cross beam of the pylon, which ties the two pylon legs together, 48 tendons are utilized. This cross beam acts as a tie beam, crucial for maintaining the structural integrity of the bridge deck. The lower section of the beam incorporates 30 tendons, while the upper section includes 18 tendons. Both longitudinal and transverse tendons are applied to provide comprehensive structural support. Each strand is made with 7 plies in which the core ply is called **king wire** and rest 6 wires are twisted on this wire to form a strand.

Quality and Strength of Materials

High-quality, high-strength steel is used for the tendons, providing up to four times the strength of conventional reinforcement steel. The tendons are designed to withstand high stress levels, with a maximum stress of up to 80% of their ultimate load capacity, and potentially increasing to 95% under specific conditions. This ensures the structural elements can endure significant loads and stresses, contributing to the bridge's overall durability and stability.

Types of Post-Tensioning Systems

There are two primary types of post-tensioning systems:

1. **Bonded Systems**: Tendons are positioned inside ducts and filled with grout after stressing. This creates a bond between the steel and concrete, ensuring any strain in the concrete is also experienced by the tendons.

2. **Unbonded Systems**: Tendons are anchored only at the ends, with no bonding along their length. This allows for independent movement of the tendons relative to the concrete, preventing direct strain translation.

Benefits of Post-Tensioning

Post-tensioning provides several advantages that make it an ideal choice for the Viaduct 2 Cable-Stayed Bridge:

- **Enhanced Load-Bearing Capacity**: It increases the bridge's ability to support heavy traffic and withstand adverse weather conditions.

- **Durability**: The method offers greater resistance to cracking and damage, extending the bridge's lifespan.

- **Design Flexibility**: Allows for the construction of slender, longer-span structures with unique geometries.

- **Material Efficiency**: Reduces the amount of concrete and steel required, lowering construction costs and improving efficiency.

- **Sustainability**: The reduced use of materials translates to a smaller carbon footprint, making it a more sustainable construction choice.

SURVEY ANALYSIS

Survey is the most important aspect of construction before start working, during construction and after the construction as well. Because it is essential to track whether the structure we are constructing is on the right track or not, so one must be skillful as well as attentive.

In this project, a preliminary survey was done very earlier in 1990 which includes making contours of the terrain, marking biodiversity, slope angles, etc. After getting the coordinates of the terrain, a suitable design was made with accurate reduced levels of points of superstructure and substructure.

FIGURE 11: TOTAL STATION BEING SET UP NEAR P2R FOR SURVEY; IT IS KEPT IN PLACE WITH THE HELP OF BARS

After concreting of the structure for each lift, coordinates are measured from a fixed bench mark where total station is placed. Coordinates of each designated point of the structure is then matched with the design coordinates. If there is minimal permissible error its fine to go with otherwise necessary concreting or chiseling is to be done.

Each corner of pylon is designated with pre numbering as per design which is used to match the coordinates of that point after taking their coordinates using total station.

Survey instruments must be calibrated from time to time and some techniques need to be defined for calibration. One such technique is **binary algorithm** for auto level calibration. In this method, the auto level is first placed at center of 100m apart poles and readings are observed. Then the position is set from 50:50 to 90:10 and it is performed continuously till we reach a complete cycle. Errors are calculated on these readings and based on it suitable correction needs to be done.

EQUIPMENTS

- **Tower Cranes: -** Four tower cranes are used in this project at each of the four pylons with a capacity of 20 ton each. They are used for various purposes such as lifting climbing formwork, all necessary heavy working equipments and for easy access of workers to reach quickly to piers top because elevators are not established on piers. Also counter weights are placed on one end of the crane arm to be in equilibrium. These cranes are supported by two supports at equal distance attached to pylons.

- **Transit Mixers: -** Concrete mixers of capacity 4 cum are used to transport concrete from the batching plant to site location, which will be used for concreting either through pipe or bucket. They have rotating mixers which keeps the concrete in motion and prevent pre-setting of concrete.

- **Dumpers: -** Trucks of variable sizes are used to carry necessary materials from casting yard to site location such as supporting formwork steel girders, railings, wooden blocks, etc.

- **Welding Machine: -** Welding is done for creating steel formwork and thus their transformer controllers are established at every pylon.

- **Vibrators: -** Needle vibrators are used in compaction of concrete so that each and every corner of structure is filled completely and there should not be any chances of weakening the structure.

- **Survey Equipments: -** Surveying equipments such as total station, auto level, GPS, reflector prism target, etc. are utilised. Prism target with three parts are used because it can be easily carried to top then assemble it.

- **Hydraulic Jacks: -** These are used everywhere at the site such as lifting climbing formwork, opening bucket for concreting, post tensioning of strands of tendons, maintaining elevation of cross beam support structure, etc.

CONCLUSION

The Mumbai-Pune Missing Link Expressway Project, undertaken by the Maharashtra State Road Development Corporation (MSRDC) and executed by Afcons Infrastructure Limited, stands as a significant advancement in enhancing the connectivity and travel efficiency between Mumbai and Pune. Through my internship, I had the opportunity to closely observe the meticulous planning, execution, and innovative engineering practices employed in this project. The construction of critical structures such as the Viaduct 2 cable-stayed bridge, with its towering pylons and advanced post-tensioning techniques, exemplifies modern engineering excellence. These efforts not only aim to reduce travel time and congestion but also enhance safety and reliability for commuters.

This project highlights the essential role of cutting-edge technology and rigorous quality control in large-scale infrastructure developments. The implementation of Automatic Climbing Formwork, precise batching plant operations, and thorough quality assurance protocols underscores the commitment to maintaining high standards. Additionally, the integration of health, safety, and environmental measures ensures a sustainable and safe working environment. Overall, the Mumbai-Pune Missing Link Expressway Project is poised to become a landmark achievement, significantly contributing to the region's transportation infrastructure and setting a benchmark for future projects.

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