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Developing Strategic Safety Guidelines for Pier Construction and U-Girder Erection in Elevated Metro Projects

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Abstract

Visited the Larsen and Toubro Construction Metro project site location in Chennai, India where around 500 workers were working on this 10 km project. This Larsen and Toubro private limited core specialized service is the construction of the metro project. Larsen and Toubro is having many other services also other than construction services. In this metro project construction of Bridge, Track, Station works & TPSS (Traction power substation) are being carried out. Construction of an elevated metro project site involved several activities that are both routine and non-routine. It was observed that two major risk activities and choose the routine activities that are carried out on a daily basis on the live road. Pier Construction, Pier Cap, U Girder Transportation and Erection activities are risky activities that involve public and machinery movement. Executing this activity without causing any lost time, injuries, or property damage to the public is a very challenging task. To address these hazards, I provided the suitable control measures based on my observation & Recommendations. These recommendations were aimed at reducing the risks and hazards involved and ensuring the safety of everyone involved in the project. I worked closely with the site execution team and engineers to coordinate the implementation of these Control measures. The controls that were put in place to reduce the risks and hazards associated with the activities mentioned were carefully considered, and most of them have been successfully implemented. I am confident that these measures will be effective in mitigating the risks and hazards associated with the pier and pier cap erection activity. The successful implementation of these control measures is crucial in mitigating the risks and hazards associated with the pier and pier cap erection activity. It's also impressive to note that these measures are improving time management, increasing production, and ensuring the topmost safety of the workers.

1. Introduction

Elevated metro construction projects involve complex and high-risk activities, particularly pier construction and U-girder erection, which are critical components in the development of elevated

tracks and viaducts. These activities often require heavy lifting operations, work at heights, and rigorous safety protocols to mitigate the risks to workers and ensure successful project completion. This literature review aims to develop Satategic safety guidelines based on site visit observations, focusing on the key safety challenges and best practices for Pier construction and U-girder erection in elevated metro projects. Pier construction is one of the most critical aspects of elevated metro systems, as piers provide the necessary support for the superstructure and elevated tracks. These activities involve significant risks due to the heavy machinery used, the complexity of lifting and positioning structural components, and the work performed at height.The U-girder erection process involves lifting and positioning large pre-cast or cast- insitu U- shaped girders that form the foundation for the track system in elevated metro projects. This operation requires precision and is associated with significant risks due to the weight of the girders, the height of the work, and the complexity of the lifting process [1]

2. Methods of Work

2.1. Pier Construction

- Pier starter reinforcement should be fixing to be done as per site requirement
- Pier starter shutter to be fixed by use of crane and alignment to be done and proper supports to be ensured and concreting to be done.
- After 24hrs de shuttering should be done.
- Area of scaffolding to be compacted properly before erection of scaffolding.
- Scaffolding Erection should be done as per approved drawing by competent scaffolders, in supervision of scaffolding supervisor and inspection should be carried out by scaffold inspector and tagging should be done.
- Ensuring all scaffolding parts access ladders, braces, brackets, boards, couplers, base plates and guard rails should be visually inspected before erection.
- Working platform should be fully boarded before starting of pier reinforcement fixing.
- After completion of pier reinforcement fixing proper anchoring support should be provided. [2]
- Ledgers should be removed on traffic directions on both sides for fixing of shutter.
- After placing of shutter ledgers with tube/couplers should be refixed on outer side.
- Ledgers and cup lock across the traffic direction should be removed and shutter should be fixed.
- After placing of shutter ledgers with tube/couplers should be refixed on outer side.
- And Walkway platform should be provided on working area.
- Sufficient lighting arrangements should be provided during Night work
- Proper Barrication arrangements shall be provided at work location
- Proper Road diversion shall be provided

2.2. Erection Activity

2.2.1. Pier Cap Erection

- Existing ground surface shall be firm & compacted before positioning of crane & trailer for erection.
- Area shall be leveled using excavator & shall be compacted with vibratory baby roller.
- Area shall be compacted well to achieve 95% of MDD of material.
- Entire area in the domain of crane boom movement shall be made free from any obstructions/utilities etc.
- Utilities and overhead obstacles shall be checked before positioning of crane & trailer for erection works.
- The access and egress to work zone shall be checked to ensure the safe entry and exit of the crane.
- Necessary check for overhead clearances, wind speed shall be made & the erection will be allowed only after overhead clearance is made and wind speed is normal.
- Any unauthorized entry will be strictly prohibited by clearly demarcating work zone.
- All lifting tools and tackles and hydraulic jacks shall possess valid third- party inspection certificates.
- Opening areas will be provided with sufficient number of securities/marshals and

total area will be covered with A Frame barricade to control un-authorized entry.

- Shifting of materials will be done between 10pm to 5am.
- The Relevant IRC sign boards to be implemented in advance to the work zone at the time of erection
- Survey axis of both faces of Pier cap shall be suitably marked before lifting.
- Lifting frame for pier cap shall be fabricated as per approved drawing.
- Lifting of pier cap from the stacking yard shall be done with gantry girder attached with Pier cap lifting frame as per approved lifting arrangement drawing.
- All necessary safety checks for the trailer shall be done before lifting of pier cap as per attached checklist
- Pier cap shall be loaded on multi-axle trailer of capacity not less than 70MT& is secured in position properly with necessary tools & tackles.
- Separate lifting plan shall be submitted for Lifting of Pier Cap prior to start of the lifting activity along with all crane & operator details as per Contractual requirements
- The route of transportation shall be pre-decided and all approvals from the concerned authorities, field erection team shall be taken prior to the transportation of Pier Caps from precast yard up to the erection point. Safety checklist for the lashing & other arrangements have been attached. [3]
- The transportation of the Pier Caps will commence only after getting confirmation from erection location that the site is ready for erection.
- Necessary cushion pads shall be used while transportation in order to avoid any cracks in the structure.
- Mockup run to be done with empty trailer from loading point to erection point prior to start of Transportation of Pier cap.
- Necessary Pilot Vehicle, Impact Protection Vehicle and sufficient number of banksmen should be provided while transportation.
- Sufficient banksmen will be provided with flags and baton lights for giving directions.
- During heavy rains, pier cap will not be transported.
- If it rains after starting of transportation, necessary precautions will be taken.
- The erection crane & trailer shall be moved to the pre-marked location for erection of pier cap.
- Aligning of crane shall be done & wooden planks steel plates (3mx2m) will be put at the out-riggers location to ensure uniform distribution of load.
- The erection of Pier cap shall be done with single hydraulic crane capable of lifting a pier cap of weight (70-75MT).
- Pier cap shall be lifted from trailer with hydraulic crane attached with lifting frame & radius of crane operation shall be less than 9.6mtrs with maximum boom
- length limited to 30m or as per crane load chart. A minimum adequate width of Row (swing area plus 5meter) will be ensured for erection operation. Safety checklist for lifting operations hasbeen attached.
- Pier cap shall be rotated clockwise or counterclockwise 90 degrees, to true orientation cap as per drawing.
- Positioning & synchronization of the 4 number of hydraulic jacks placed over stressing frame shall be rechecked prior to the placing of pier cap over the lifting frame.
- Pier cap shall be lowered on the lifting frame & both pier cap along with lifting frame shall be lowered further with hydraulic jacks.
- Pier cap shall be aligned to true line & level over pier using jacks, within ± 5-10 mm accuracy.
- The survey engineer will check the line, level and final positioning of the Pier cap and will suggest for adjustment required if any. Survey record shall be maintained in attached checklist.
- Gap (if any) in between pier cap bottom & pier top level is observed after final adjustment shall be filled with Non shrink cementitious grout of M50 Grade.
- For lifting & lowering operation only one authorized signal man will be made

responsible to ensure seem less erection operation.

- Once lifting is completed, trailer will be moved to casting yard and will not be parked on site.
- Reverse horn, camera and banksmen will be provided while reversing of vehicle.
- For transportation & erection of Pier cap, it will take 5 to 7hrs. [4]

2.2.2. U Girder Erection

Site preparation work- Area levelling, compaction and strengthening if required (applicable for the off-road working) is always. Same procedure like as pier cap erection

- Installation of staging towers, access towers & hand-railing.
- Placing of bearing and steel wedge plate.
- Lifting of U-Girder from stacking yard & loading on trailer.
- Transportation of U-Girder from loading point to erection site.
- Erection by pair of mobile cranes
- Alignment and final checking.

The U-Girder shall be transported from the stacking yard to the erection points by means of Hydraulic Multi Axle trailers. All legal documents for Hydraulic Multi Axle trailer and operator shall be submitted for Engineers' verification. It is necessary to have a firm ground for placement of cranes and trailer for loading activity. Ensure the ground shall be levelled, consolidated, and compacted.

- U Girder Transportation from Precast yard to the Site Erection Location
- Road Diversion for the U Girder Erection Activity and Alternative Road arrangements for public transport [5]
- Placement of Tire mounted Telescopic cranes on the live road for the U Girder Erection
- Outrigger positioning for the Crane and Counterweight installation for the Cranes
- Lifter beam installation in the U Girder for lifting
- RA/MS Briefing for the U Girder Erection activity with Erection
- Downline and Upline U girder Lifting and Erection
- Alignment for the Both Upline and Downline U Girder
- Before the start of erection, loose debris/Unwanted material shall be removed.
- For maintaining Safe Traffic flow, Water board/ Hard barricade (If required) to be placed as mentioned in the attached drawing.
- Sufficient illumination shall be provided for the erection of the Planned Location.
- While Erecting the U-Girders, the Gap between the U-Girder shall be 50mm (Transverse direction) for fixing the expansion joint as mentioned in the Drawing.
- Ensure, during erection, the precast units should be protected against damage caused by local crushing and chafing effects of lifting and transport equipment.
- Before the start of erection, hard hand railing by 40 mm MS Pipe or similar kind should be made available at the top of both Pier caps of the span planned for U- Girder Erection as fall protection arrangement for the personnel at height.
- The erection of Precast U-Girder shall be done by means of using two capacity cranes not less than 500 MT each Erection by means of two mobile cranes [6]
- Lift plan shall be made ready for each span location before each erection using two cranes capable of lifting a total load of 190 MT.
- However, in no case radius of crane operation shall be more than prescribed boom length & radius as per load chart.
- A minimum adequate width of Row (swing area plus 5 meter) from the center line of the pier will be ensured for erection operation.
- Lifting hole Location shall be grouted after the completion of U-Girder Erection with approved materials, PVC pipes shall be removed before grouting.
- Lift Plan should be prepared for each span location clearly mentioning the span ID and the lift plan should be certified.
- If any changes in the lift plan are required as per the site situation, the same needs to be incorporated and validated by erection in-charge [7]

3. Strategic Safety Guidelines

3.1. Strategic Safety Guidelines for Pier Construction

- Ensure that temporary supports (e.g., bracing and shoring) are in place during all phases of pier construction to prevent

collapses.

- Develop detailed lifting plans for all crane operations, including pre-lift checks, load calculations, and safety protocols.
- Establish a robust fall protection plan with guardrails, safety nets, and full-body harnesses for all workers involved in elevated work. [8]
- Regularly inspect and certify all scaffolding and lifting equipment to ensure compliance with safety regulations.
- Ensure workers undergo proper training for working at heights and safe (Figure1)

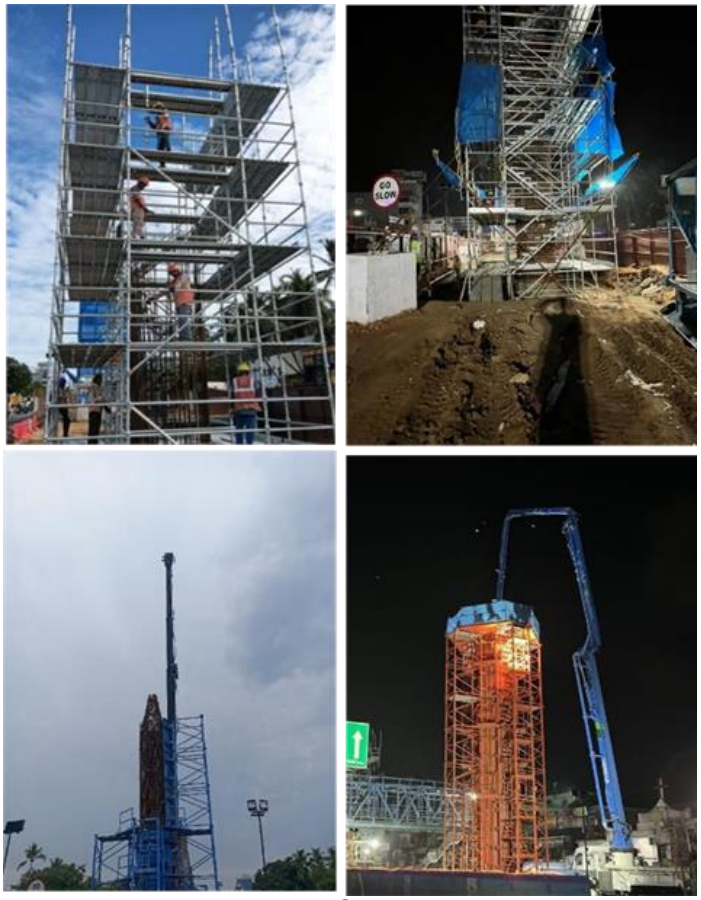

Figure 1 Process of Pier Construction

3.2. Strategic Safety Guidelines for Pier cap & U-Girder Erection

- Develop a comprehensive lifting plan that addresses crane capacity, wind conditions, and load calculations for each U-girder placement. (Figure 2)
- Ensure that rigging is done correctly with appropriate equipment (e.g., slings, shackles, hooks) and that load stability is continuously monitored during the operation.
- Provide fall protection systems such as guardrails and harnesses for all workers involved in the lifting operation.
- Pre-emptively assess weather conditions and halt operations if wind speeds or other environmental factors pose a risk to safety.
- Establish communication protocols (e.g., walkie talkie, radios, hand signals) between crane operators and ground personnel to coordinate the operation effectively. [9]

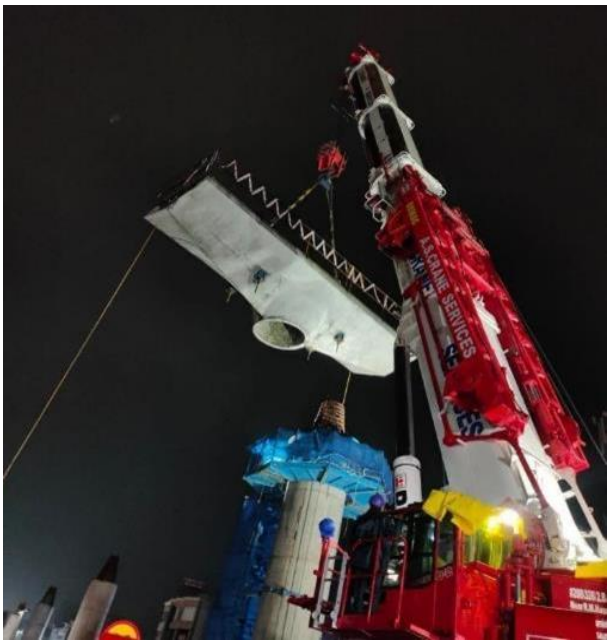

Figure 2 Process of Pier Cap Erection

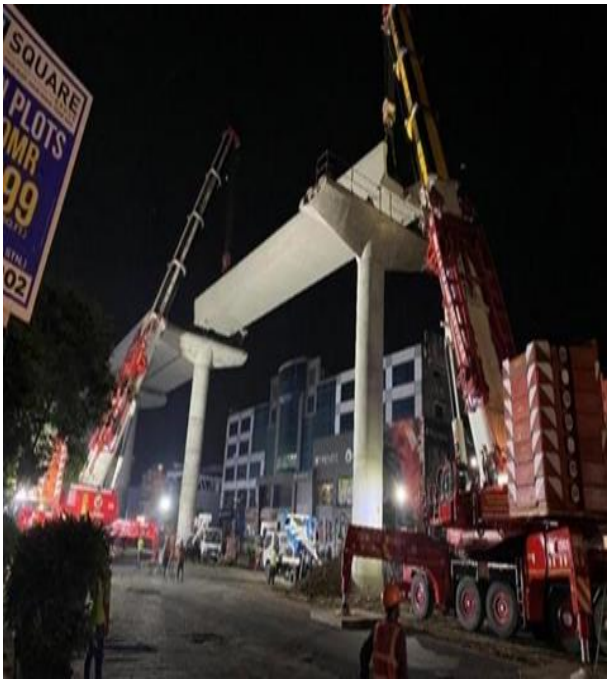

Figure 3 Process of U Girder Erection

4. Results and Discussion

Table 1 Findings & Possible Outcome of Pier Construction

S.No	Occurrence	Possible Symptoms /Consequences	Possible Outcome
1	Counter block capacity and awareness signage not displayed for counterweight of Pier	Risk of overloading counterweights, leading to instability or failure	Counter block capacity and awareness signage displayed
2	Guide rope arrangement tied by Substandard rod for pier protection instead of Turn buckles arrangement which may cause fall hazard	Increased risk of fall hazards due to improper rope securing, potential failure.	Guide rope arrangement tied by Substandard Turn buckles arrangement rod for pier protection
3	Insufficient U-Bolt 12mm Bull dock clamps for pier protection. Three numbers are to be tied in right way by using the Live end and Dead-end rope	Risk of rope slippage or failure, leading to accidents or equipment malfunction.	Sufficient U-Bolt 12mm Bull dock clamps were provided for pier protection
4	D-Shackle and Bow shackles were observed without Monthly inspection Colour code	Unsafe lifting operations, risk of shackle failure during load handling	Monthly inspection Color code D-Shackle and Bow shackles
5	Safety Catch net is to be tied in scaffolding side for providing additional safety	Lack of additional fall protection, increasing risk of worker injury or death	Safety Catch tied in Scaffolding side for providing additional safety
6	Guard rail setup is to be done, and all scaffolding materials are to be used without missing	Increased fall hazards for workers, potential for serious injury	Guard rail arrangements were provided for scaffolding
7	Proper access provision is to be provided, and Guard rail arrangement is to be done	Unsafe access increases risk of falls or accidents on elevated platforms	Proper access provided
8	No Proper provisions are provided for draining the water all around the basement of the scaffolding structure	Water accumulation leading to slippery surfaces, increasing fall risks	Dewatering arrangement done
9	Improper scaffolding Procedures were followed without regular update of inspection tag	Risk of using unsafe scaffolding, leading to collapse or worker injury	Training program given regarding SOP scaffolding erection and safety measures
10	Improper guard rail arrangement provided all most all of the scaffolding top of the platform in the pier staging	Fall hazard for workers, especially on top of the platform in pier staging	Guard rail arrangement provided all most all of the scaffolding top of the platform in the pier staging
11	Single grating is used during the fixing of the shuttering which is unsafe	Unsafe platform, increased risk of accidents or falls due to insufficient support	Single grating removed from working platform
12	Electrical Power cable found on Ground near Vehicle movement Area	It may cause serious Electrical Hazards	Electrical Power cable removed from ground
13	Oil & Chemical Container found at site without MSDS	Increased risk of Skin irritation, Respiratory issues, Eye irritation, Long-term exposure	MSDS Displayed in all the chemical

Table 2 Findings & Possible Outcome of Erection Activity

S. No	Occurrence	Possible Symptoms /Consequences	Possible Outcome
1	Sufficient number of bracing provisions is not available	Risk of collapse and worker injury	Sufficient number of bracings provided
2	Proper guard rail provisions are not provided in the pier cap platform	Fall hazards for workers, potential fatalities	Proper guard rail provided in the pier cap platform
3	No proper anchoring point is provided for the full body safety harness in the pier cap platform.	Increased fall risk, severe injury or death	No proper anchoring point provided
4	Toe board provision is not available at the inner side of the collar assembly, Pier cap to prevent materials, fall in downside.	Materials may fall, causing injury	Toe board available at the inner side of the collar assembly
5	Between the floor there is gap found which will allow the materials to fall in the road at the collar assembly.	Materials may fall, creating hazards	Floor opening closed
6	There is no proper safe access to reach the platform from staircase to pier cap platform & pier arm platform	Increased risk of falls and injuries	Proper safe access provided to reach the platform from staircase to pier cap platform & pier arm platform
7	During the erection of pier arm the workers stand under the suspended load	Risk of injury or death from dropped load	Awareness training given and Proper barricading, Signages provided
8	Monthly color code not maintained on wire rope sling	Risk of using uninspected slings, sling failure	Monthly color code maintained
9	No Gate Arrangements for U Girder Staircase to avoid Unauthorized entry	Unauthorized access, increased risk of accidents	Gate Arrangements provided for U Girder Staircase to avoid Unauthorized entry
10	Authorized Driver/Operator details not displayed on Vehicle cabin	Lack of accountability, unsafe operations	Authorized Driver/Operator details displayed on Vehicle cabin & QR Code also generated
11	No Sufficient Reflective Stickers and Rope light arrangements at Diversion point and U Girder for safe Transportation	Poor visibility, risk of accidents	Sufficient Reflective Stickers and Rope light arrangements provided at Diversion point and U Girder for safe Transportation

4.1. Results

It is crucial to ensure the safety of workers in a construction site, especially when dealing with a large number of employees. In order to minimize or eliminate potential hazards, identifying, monitoring, and reducing risks to an acceptable level is necessary. During a visit to the Phase 11 project site, I observed some significant safety issues and provided recommendations for suitable control measures to rectify them. Efficient control

measures were implemented on the site to reduce accidents and incidents. One of the major issues was work at height, and proper alternative access control measures were proposed and implemented with the help of the site team. After analyzing the lifting activity, suitable lifting methods were proposed to enable the system to function effectively with the site controls. One of the major implementations was the use of QR codes in the Phase 2 project, which enabled effective inspection and was highly appreciated by CMRL and the site team. Overall, it is important to prioritize safety in construction sites, and implementing suitable control measures can help ensure the well-being of workers. The implementation and control measures put in place for Phase 2 of the project have had a significant impact on time management and worker safety. With these measures, workers are able to complete their tasks in a safe and efficient manner, ensuring that the project is successful. The improvements made are essential for ensuring that the work is completed on time and with the highest level of safety, which is always a top priority. [10]

4.2. Discussion

Elevated metro construction projects involve complex and high-risk activities, particularly pier construction and U-girder erection, which are critical components in the development of elevated tracks and viaducts. These activities often require heavy lifting operations, work at heights, and rigorous safety protocols to mitigate the risks to workers, Public and ensure successful project completion. The objective of the project is to develop Satategic safety guidelines based on site visit observations, focusing on the key safety challenges and best practices for Pier construction and U-girder erection in elevated metro projects.The Control measures which is given for the Potential hazards will be effective to rectify the issues at the Elevated metro construction. This New implementation which will be effective for the project growth by reducing the accidents while doing the construction. The Expected outcome of the potential hazards is well assessed from the additional suitable control measures [11]

Conclusion

The development of Strategic safety guidelines for pier construction and U-girder erection in elevated metro projects is crucial for minimizing risks and ensuring the safety of workers. The key to effective safety management lies in:

- Developing detailed lifting plans for heavy lifting operations, ensuring proper equipment inspections, and maintaining effective communication during the operations.
- Implementing robust fall protection systems for workers involved in elevated tasks, including the use of guardrails, safety nets, and personal fall arrest systems.
- Ensuring that all equipment and scaffolding are regularly inspected and that workers are adequately trained in height safety protocols.
- Continuously monitoring environmental and site conditions to assess potential risks and take corrective actions when necessary.
- By following these guidelines and prioritizing safety, metro construction projects can mitigate risks, reduce accidents, and ensure a safe working environment for all personnel involved in pier construction and U-girder erection activities

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