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To Analysis and Design of Cantilever Metro Station Concourse Cross-arm

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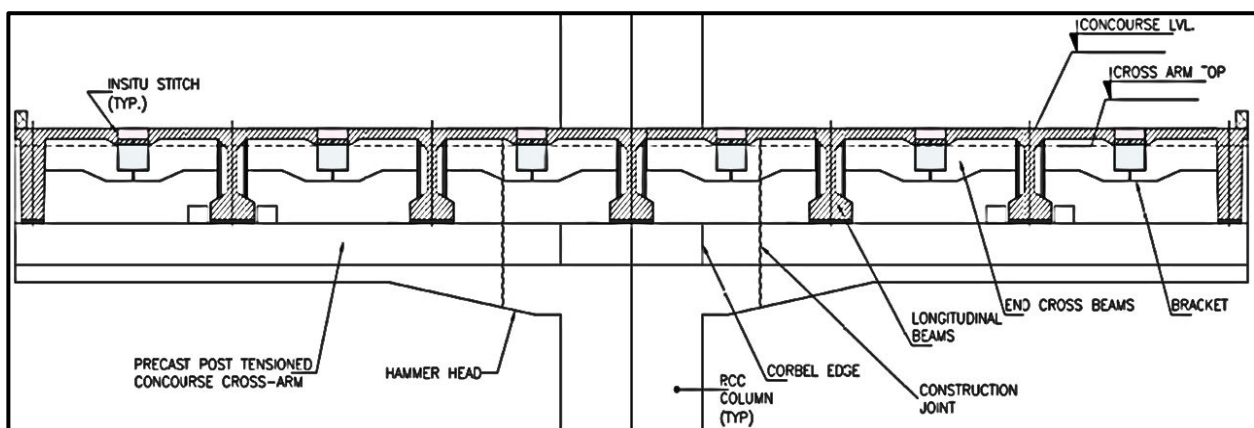
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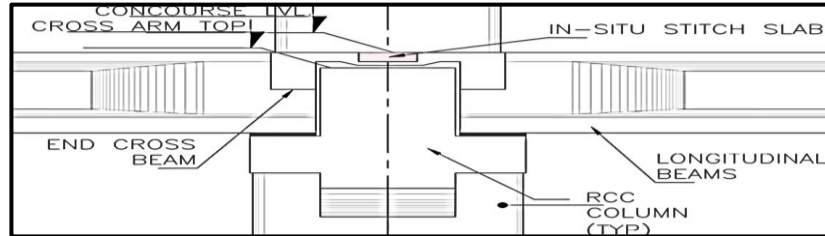
ABSTRACT: Due to severe space limitations in urban metro stations, traditional portal frames aren't feasible. This project focuses on designing inverted T-shaped, post-tensioned concrete cantilevered cross arms that extend from a central pier. These arms support longitudinal beams with a flush top surface, a critical design choice to optimize vertical space and eliminate the need for additional transverse piers. To overcome a 10.5-meter cantilever span and height restrictions of 5.9 meters, post-tensioned concrete was essential. This method allows for a shallower section, increases span capacity, and improves crack control and deflection, making a 21-meter total span possible where conventional reinforced concrete would be impractical. The design involved meticulously optimizing the post-tensioning cable profile to control deflections and stresses, ensuring an economical and standardized solution that will benefit the contractor with faster construction and enhanced efficiency for the multiple identical cross arms needed.

I. INTRODUCTION

To navigate severe space constraints in urban metro stations, this project utilizes an inverted T-shaped, post-tensioned concrete cross-arm that acts as a horizontal cantilever. Extending 10.5 meters from a central pier for a total span of 21 meters, this design supports the concourse floor's longitudinal beams. The primary challenge is a 5.9-meter height restriction below the cross-arm, which makes a conventional reinforced concrete design with its deep section impractical. Therefore, a post-tensioned design is adopted. This method offers several key advantages: a shallower section that meets the height restriction, increased load-carrying capacity for the 10.5-meter span, improved crack control for enhanced durability, and reduced deflections for greater stability.



The cross-arm's inverted T-shape is critical for structural efficiency. Its deep web is the primary vertical element that resists bending and shear forces. It's designed to be wide enough to accommodate the post-tensioning tendons, anchor plates, and utilities like electrical cables, keeping the concourse uncluttered. The flanges, located at the bottom of the cross-arm, significantly increase its bending resistance and reduce deflections. They also act as corbels, providing a stable, wide-bearing surface for the longitudinal beams, which simplifies connection design and reduces bearing stresses.



Ultimately, the deep web and flanges work together to create a structurally efficient, space-saving design. This allows for a shallower section that addresses height restrictions while providing enhanced performance and simplified connections, making it a highly effective solution for this challenging metro station project.

II. OBJECTIVE

The objective is to design a first-of-a-kind, inverted T-shaped, post-tensioned concrete cross-arm for a metro station concourse. The design will adhere to the provisions of building design code IS 1343, specifically focusing on maintaining permissible stress levels and controlling crack width. This solution aims to overcome severe height and space constraints, enabling a 21-meter total span with a shallow section, where conventional reinforced concrete would be impractical.

Scope of Work

This study's scope is to design a sustainable and cost-effective prestressed pier cap. The design process will include: Vertical Cable Profile Optimization: Meticulously analyze and optimize the vertical curvature of the prestressing cables. This is crucial for controlling prestress losses, managing stress distribution, and ensuring structural integrity.

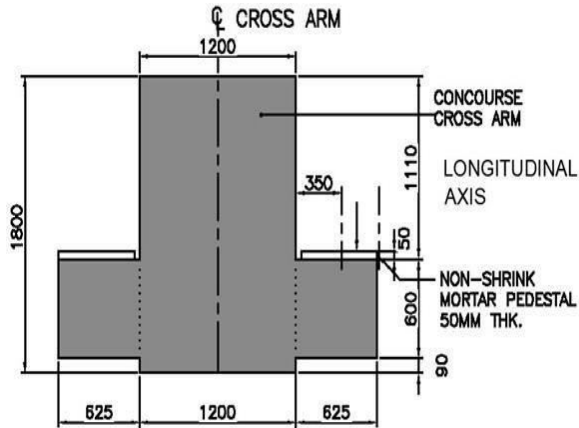
Cost-Effective Design: Develop an economical solution through the optimization of material usage, specifically by determining the minimum number of cables required without compromising safety and performance. This will also involve selecting appropriate construction methods to minimize overall project costs.

III. METHODOLOGY

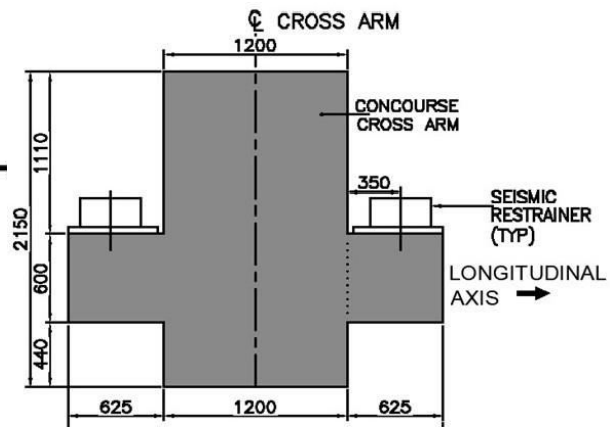
The analysis and design of the cross-arm will be conducted using a hybrid software-based approach, combining the capabilities of STAAD and MIDAS. Initially, a grillage model will be prepared in STAAD, based on the architectural and structural drawings. Loads, derived from DMRC's tender documents for a typical Indian metro station, will be applied to this model. The reactions for various load cases will then be transferred from the STAAD model to a detailed model in MIDAS, where the material and section properties of the cross-arm will be defined. MIDAS is an ideal tool for this project as it allows for a precise examination of stresses at all four corners of the cross-section. This analysis will be crucial for determining the exact prestressing requirements for the cross-arm. The stress outputs from MIDAS will be meticulously cross-verified against the permissible limits set by the IS 1343 code for both the construction and service stages. Should the section satisfy these stress provisions, a final capacity check will be performed for ultimate loading conditions. This integrated methodology is both accurate and time-efficient, ensuring a robust and economical design.

Structural data and property of cross-arm

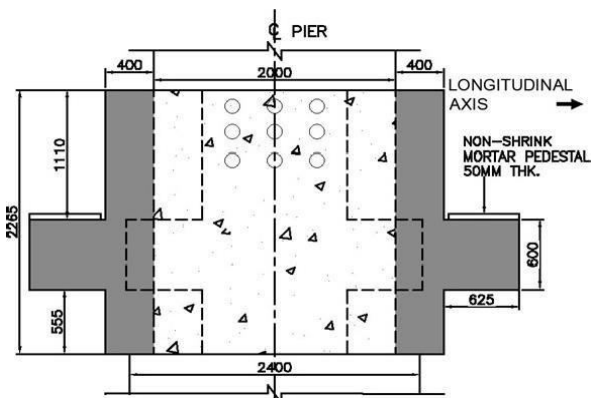
S. No.	Description	Area	Depth of Section	MOI	CG of Section from Top (yt)
		m ²	m	m ⁴	m
1	Section B – B	2.91	1.8	7.51E-01	1.031
2	Section C – C	2.91	1.8	7.51E-01	1.031
3	Section C' – C'	3.47	2.265	1.23E+00	1.193



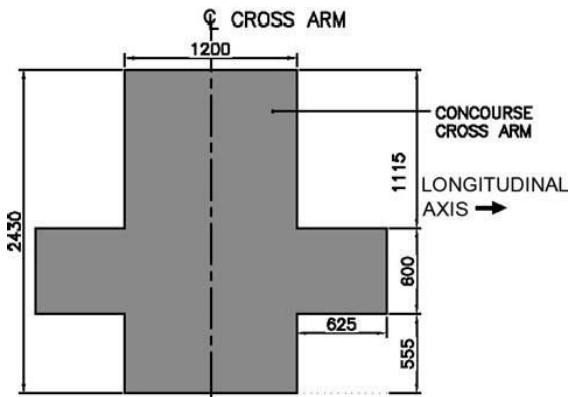
Section B-B



Section C-C

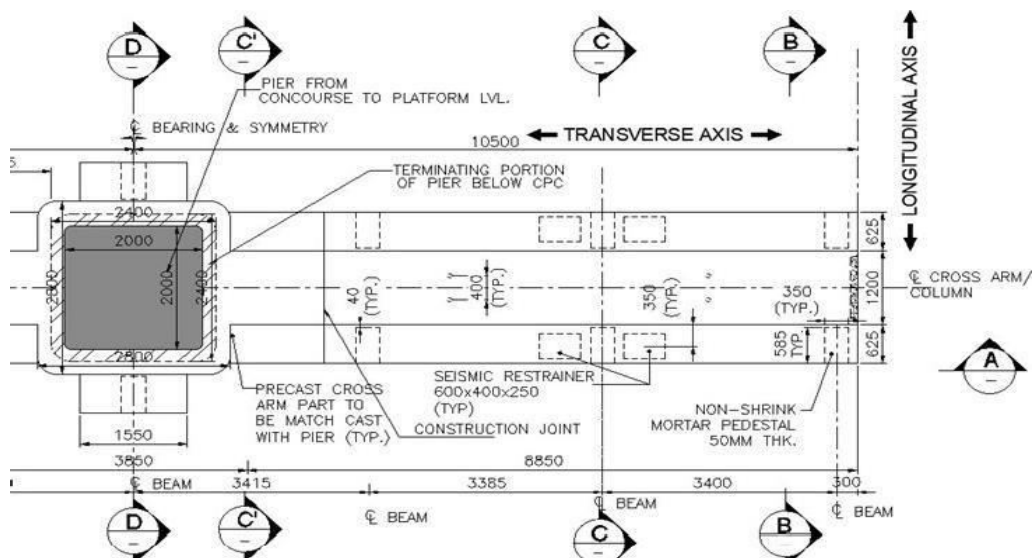


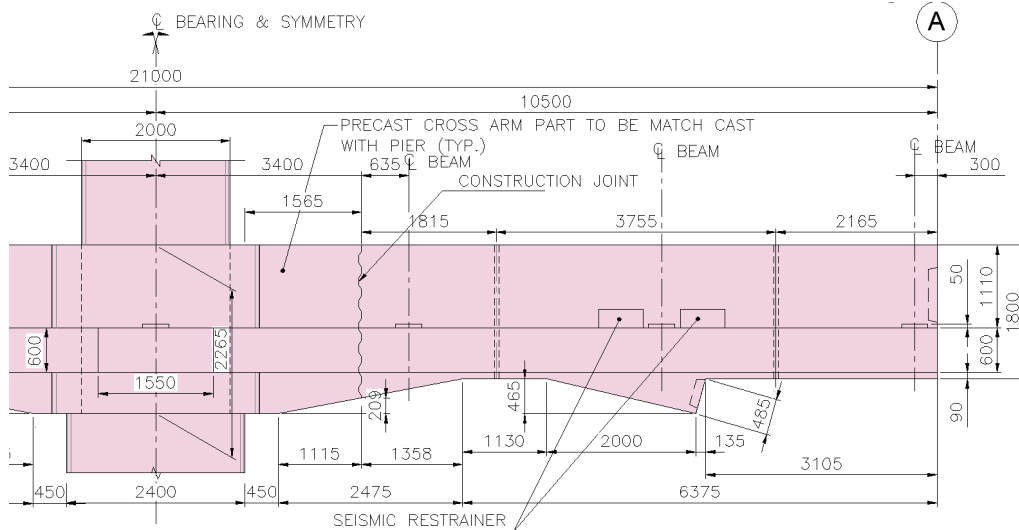
Section D-D



Section C'-C'

Top view of Cross-arm

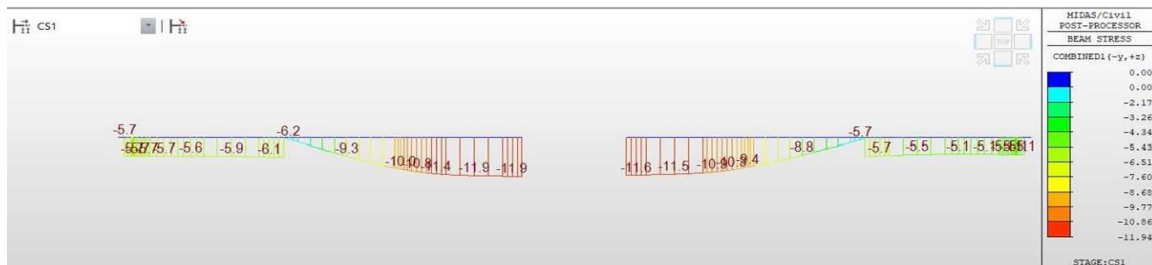




View A-A

IV. RESULTS

Construction Stage - Maximum and minimum Stress at Top and Bottom Fiber Construction Stage 1- Top Fiber Stress after PT Stage -1



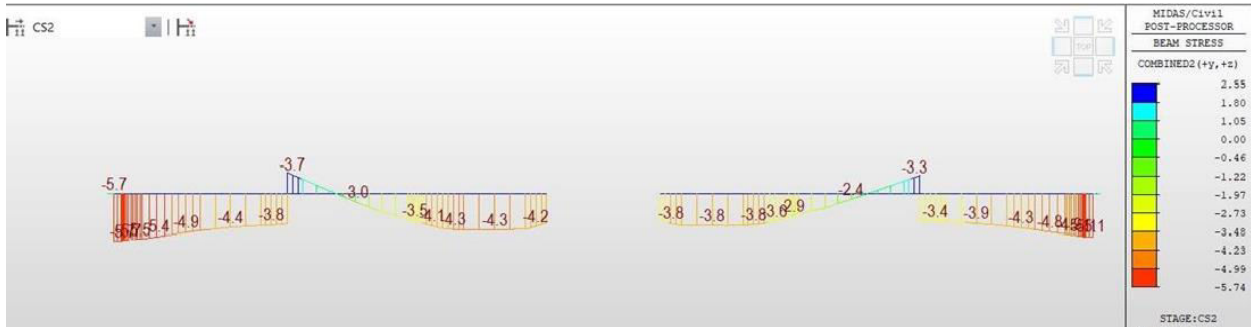
Max Tensile Stress	=	.00MPa	<	3.78MPa	OK
Max Compressive Stress	=	11.94MPa	<	20.48MPa	OK

Construction Stage 1- Bottom Fiber Stress



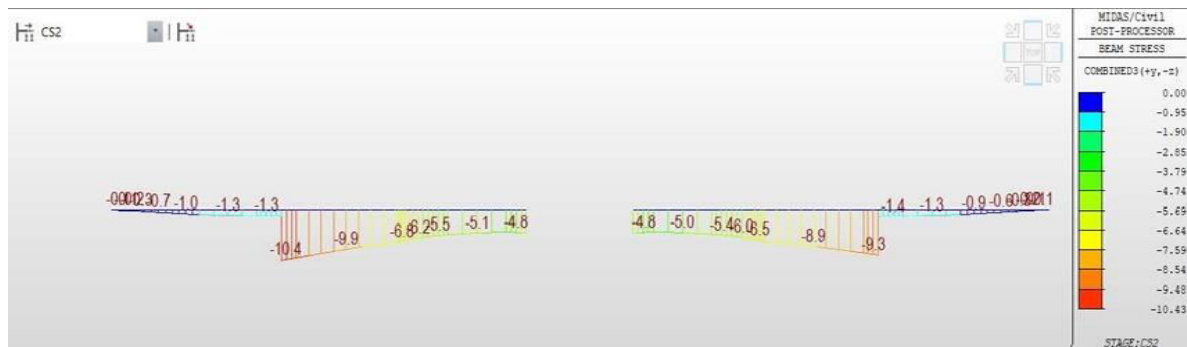
Max Tensile Stress	=	.30MPa	<	3.78MPa	OK
Max Compressive Stress	=	8.77MPa	<	20.48MPa	OK

Construction Stage 2- Top Fiber Stress after Erection of T & L Beam



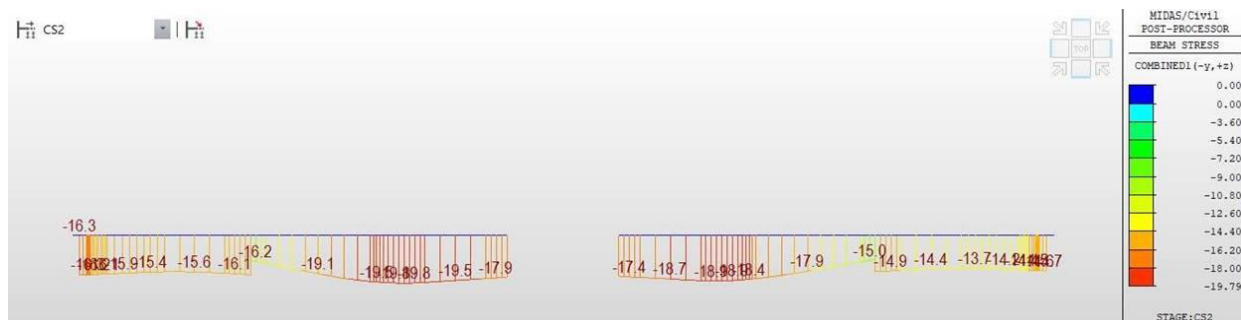
Max Tensile Stress	=	3.70MPa	<	3.78MPa	OK
Max Compressive Stress	=	5.74MPa	<	20.48MPa	OK

Construction Stage 2- Bottom Fiber Stress after Erection of T & L Beam



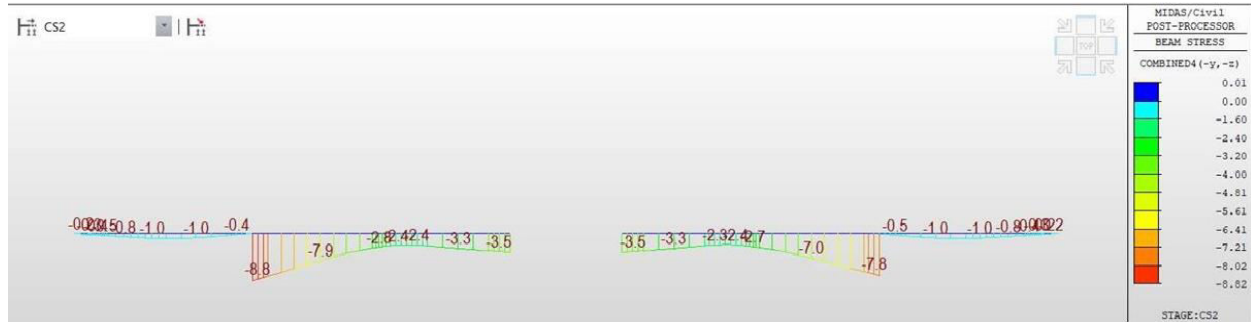
Max Tensile Stress	=	.00MPa	<	3.78MPa	OK
Max Compressive Stress	=	10.43MPa	<	20.48MPa	OK

Construction Stage 2- Top Fiber Stress after PT Stage -2



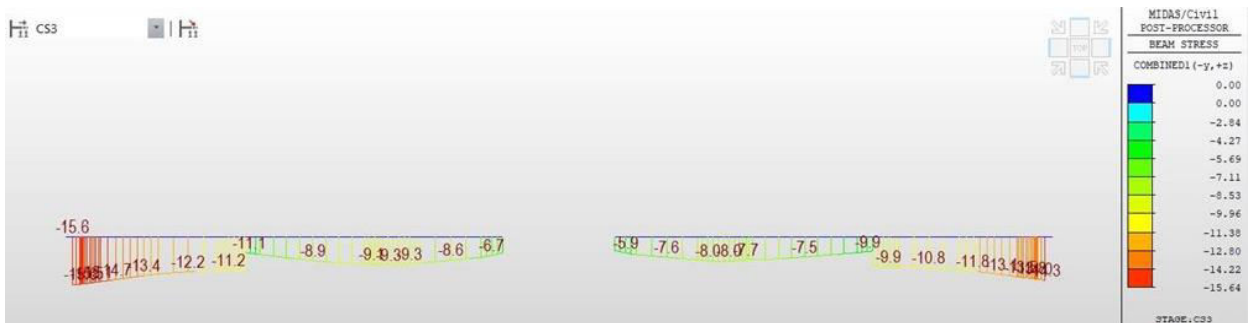
Max Tensile Stress	=	.00MPa	<	3.78MPa	OK
Max Compressive Stress	=	19.80MPa	<	20.48MPa	OK

Construction Stage 2- Bottom Fiber Stress after PT Stage -2



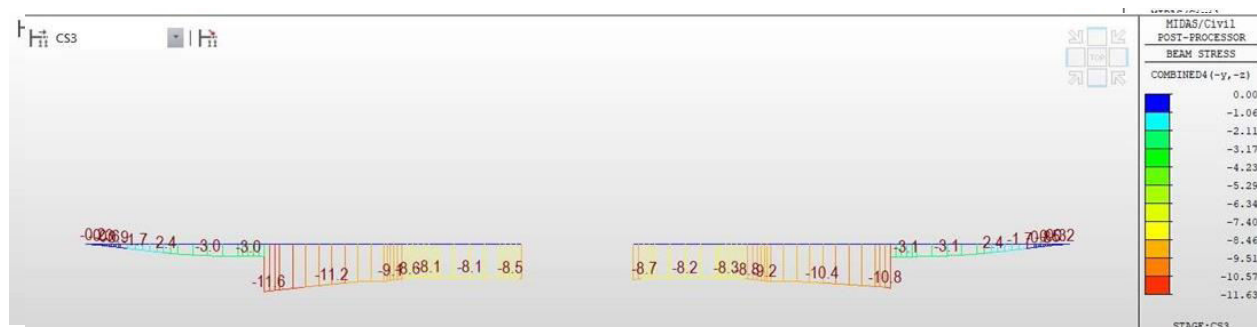
Max Tensile Stress	=	.00MPa	<	3.78MPa	OK
Max Compressive Stress	=	8.82MPa	<	20.48MPa	OK

Construction Stage 3- Top Fiber Stress after Application of SIDL



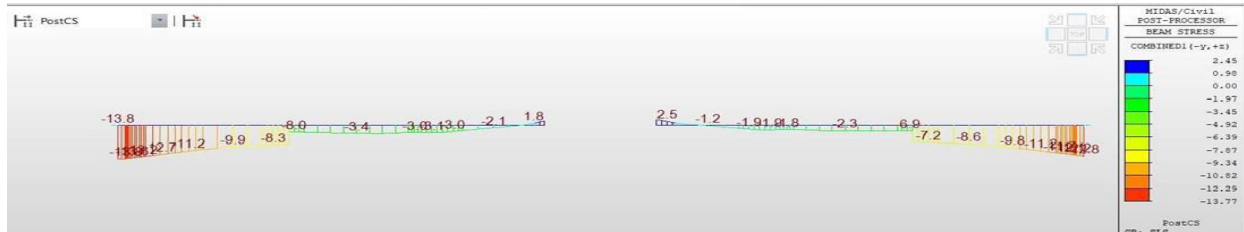
Max Tensile Stress	=	.00MPa	<	3.78MPa	OK
Max Compressive Stress	=	15.64MPa	<	20.48MPa	OK

Construction Stage 3- Bottom Fiber Stress after Application of SIDL



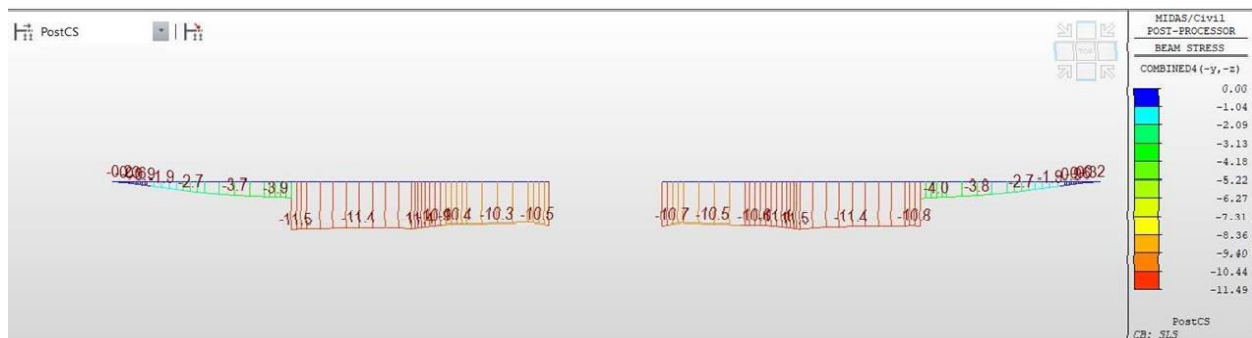
Max Tensile Stress	=	.00MPa	<	3.78MPa	OK
Max Compressive Stress	=	11.63MPa	<	20.48MPa	OK

Service Stage- Top Fiber Stress



Max Tensile Stress	=	2.45MPa	<	4.06MPa	OK
Max Compressive Stress	=	13.77MPa	<	18.50MPa	OK

Service Stage- Bottom Fiber Stress



Max Tensile Stress	=	.00MPa	<	4.06MPa	OK
Max Compressive Stress	=	11.49MPa	<	18.50MPa	OK

V. CONCLUSION

Based on the results of present study following conclusions are drawn.

- Slender and Lightweight: It allows for significantly more slender and lighter designs, simplifying on-site construction.
- Prefabrication Benefits: Elements can be prefabricated off-site for quality control and efficient assembly.
- Enhanced Durability: Post-tensioning ensures compressive stress, boosting durability and protecting against environmental wear.

Prestressed concrete is the ideal material for efficient, durable, and constructible long-span cantilever cross-arms.

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