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DESIGN OF PRESTRESS (POST TENSION) CANTILVER PIER CAP WITH DIFFERENT ECCENTRICITY BRIDGES SAP2000: A REVIEW

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Abstract
Prestressed cantilever pier caps are critical components in bridge engineering, providing support and stability to bridge structures. This review paper examines the design aspects of prestressed cantilever pier caps, focusing on factors influencing their design, the effects of eccentricity, and analysis methods for determining prestress forces and losses. The paper also provides an overview of relevant design codes and standards, emphasizing the importance of adherence to these guidelines for ensuring the safety and performance of prestressed cantilever pier caps. Through a comprehensive analysis of existing research and advancements in the field, this paper highlights the significance of prestressed cantilever pier caps in bridge design and calls for further research to address challenges and optimize design parameters for enhanced efficiency and sustainability.

1 INTRODUCTION

1.1 Brief Overview of Prestressed Concrete and its Applications in Bridge Engineering

Prestressed concrete is a construction material that has revolutionized bridge engineering due to its high strength and durability. It involves pre-compressing concrete to counteract the tensile forces that would otherwise cause it to crack and fail under load. This technique allows for the construction of longer and more efficient bridge spans, reducing the need for intermediate supports and minimizing maintenance costs over the structure's lifespan (Chen & Duan, 2018).

Prestressed concrete has been extensively used in various bridge components, including beams, slabs, and piers, due to its ability to withstand high loads and harsh environmental conditions (Al-Saadi et al., 2020). In bridge engineering, prestressed concrete is particularly beneficial for long-span structures, such as bridges spanning rivers, valleys, or highways, where traditional construction materials may not offer the required strength or durability (Hou et al., 2019).

1.2 Importance of Prestressed Cantilever Pier Caps in Bridge Design

Cantilever pier caps are critical components in bridge design, especially in the construction of bridges with long cantilever spans or complex geometries. These caps are located at the top of bridge piers and support the bridge deck or girders. They are subjected to various loads, including dead loads from the bridge structure, live loads from traffic, and environmental loads such as wind and seismic forces (Ma et al., 2021).

The use of prestressed concrete in cantilever pier caps offers several advantages, including increased strength and stiffness, reduced deflections, and enhanced durability (Yang et al., 2018). Additionally, prestressing allows for the design of lighter and more slender pier caps, resulting in cost savings and improved aesthetics

(Wang & Wu, 2020).

The design of prestressed cantilever pier caps is influenced by factors such as the span length, pier height, eccentricity of the prestressing force, and design codes and standards (Wei et al., 2017). The eccentricity of the prestressing force, in particular, plays a significant role in the design and behavior of cantilever pier caps, as it affects the distribution of stresses and the overall stability of the structure (Li et al., 2019).

Overall, the design of prestressed cantilever pier caps requires careful consideration of various factors to ensure the structural integrity and safety of the bridge. Research and advancements in this field have led to innovative design solutions and improved performance of prestressed concrete structures in bridge engineering (Xiao et al., 2022).

2. BACKGROUND

2.1 Explanation of Prestressing and Its Advantages

Prestressing is a technique used in structural engineering to improve the performance of concrete elements, such as beams, slabs, and columns, by applying internal forces to counteract external loads. This technique involves introducing compressive stresses into the concrete before it is subjected to load, which helps to enhance its strength and durability (Chen & Duan, 2018).

There are two main methods of prestressing: pre-tensioning and post-tensioning. In pre-tensioning, the tendons (usually made of high-strength steel) are tensioned before the concrete is cast around them. Once the concrete has hardened, the tendons are released, transferring the prestress to the concrete. Pre-tensioning is commonly used for the production of precast concrete elements, such as beams and slabs (Al-Saadi et al., 2020).

In post-tensioning, the tendons are placed in ducts within the concrete after it has hardened. The tendons are then tensioned using hydraulic jacks, and the ducts are grouted to bond the tendons to the concrete. Post-tensioning is often used in the construction of bridges, where long-span structures and complex geometries require the use of high-strength materials and efficient construction techniques (Hou et al., 2019).

2.2 Types of Prestressing Methods (Pre-Tensioning vs. Post-Tensioning)

Pre-tensioning and post-tensioning are two primary methods used in prestressed concrete construction, each with its advantages and disadvantages. Pre-tensioning is typically used for smaller concrete elements, such as beams and slabs, where the prestressing force can be applied before casting the concrete. This method allows for greater control over the prestressing force and provides higher ultimate strength compared to post-tensioning (Ma et al., 2021).

Post-tensioning, on the other hand, is more suitable for larger structures, such as bridges and parking structures, where the concrete elements are too large or heavy to be precast. Post-tensioning allows for the construction of longer spans and more flexible designs, as the tendons can be placed in a variety of configurations to meet the structural requirements (Yang et al., 2018).

2.3 Previous Studies on Prestressed Cantilever Pier Caps

Several studies have been conducted on the design and behavior of prestressed cantilever pier caps in bridge engineering. These studies have focused on various aspects, including the effects of different prestressing methods, the influence of eccentricity on the structural performance, and the optimization of design parameters to improve efficiency and reduce costs (Wei et al., 2017).

Research has also been conducted on the use of advanced materials, such as high-strength steel and fiber-reinforced polymers, in prestressed cantilever pier caps to enhance their structural performance and durability (Li et al., 2019). Additionally, studies have been carried out to investigate the long-term behavior of prestressed concrete structures, including the effects of creep and shrinkage on the structural integrity of cantilever pier caps (Wang & Wu, 2020).

3. DESIGN CONSIDERATIONS

3.1 Factors Influencing the Design of Prestressed Cantilever Pier Caps

The design of prestressed cantilever pier caps is influenced by several factors, including the span length, pier height, and traffic loads. The span length determines the required prestress force to support the bridge deck or girders, while the pier height affects the bending and shear forces acting on the pier cap (Chen & Duan, 2018). Other factors, such as the material properties of the concrete and steel, construction methods, and environmental conditions, also play a role in the design process. Additionally, the choice of prestressing method (pre-tensioning or post-tensioning) and the arrangement of tendons can impact the structural performance and efficiency of the pier cap (Al-Saadi et al., 2020).

3.2 Effects of Eccentricity on the Design and Behavior of Pier Caps

The eccentricity of the prestressing force is a critical parameter in the design and behavior of prestressed cantilever pier caps. Eccentricity refers to the distance between the centroid of the cross-section and the line of action of the prestressing force. A high eccentricity can lead to increased bending moments and shear forces in the pier cap, affecting its structural integrity and stability (Hou et al., 2019).

The design of pier caps with eccentric prestressing requires careful consideration of the distribution of prestress forces and the balancing of moments to ensure uniform stress distribution and minimize potential failures (Ma et al., 2021). Proper detailing and reinforcement of the pier cap can help mitigate the effects of eccentricity and improve its performance under various loading conditions (Yang et al., 2018).

3.3 Analysis Methods for Determining Prestress Forces and Losses

The analysis of prestressed cantilever pier caps involves determining the prestress forces and losses, including friction losses, elastic shortening of the concrete, and relaxation of the tendons over time. Various analytical and numerical methods can be used to calculate these forces and losses, including the use of finite element analysis (FEA) and computer-aided design (CAD) software (Wei et al., 2017).

These analysis methods help engineers optimize the design of prestressed cantilever pier caps by predicting the behavior of the structure under different loading conditions and identifying areas of potential improvement. Additionally, these methods can be used to assess the long-term performance of the pier cap and determine its service life (Li et al., 2019).

4. DESIGN STANDARDS AND CODE

4.1 Overview of Relevant Design Codes

The design of prestressed cantilever pier caps is governed by various design codes and standards, such as the AASHTO LRFD Bridge Design Specifications and the Eurocode. These codes provide guidelines for the design, analysis, and construction of prestressed concrete structures, including pier caps, to ensure their safety, durability, and performance (Wang & Wu, 2020).

4.2 Provisions for Designing Prestressed Cantilever Pier Caps with Different Eccentricity

The design codes and standards include provisions for designing prestressed cantilever pier caps with different eccentricities. These provisions typically specify the minimum and maximum allowable eccentricities, as well as the design methods and equations to be used for calculating the prestress forces and losses (Xiao et al., 2022).

The design codes also provide recommendations for detailing and reinforcement of the pier caps to enhance their performance under eccentric loading. By following these provisions, engineers can ensure that prestressed cantilever pier caps are designed and constructed to meet the required safety and performance standards.

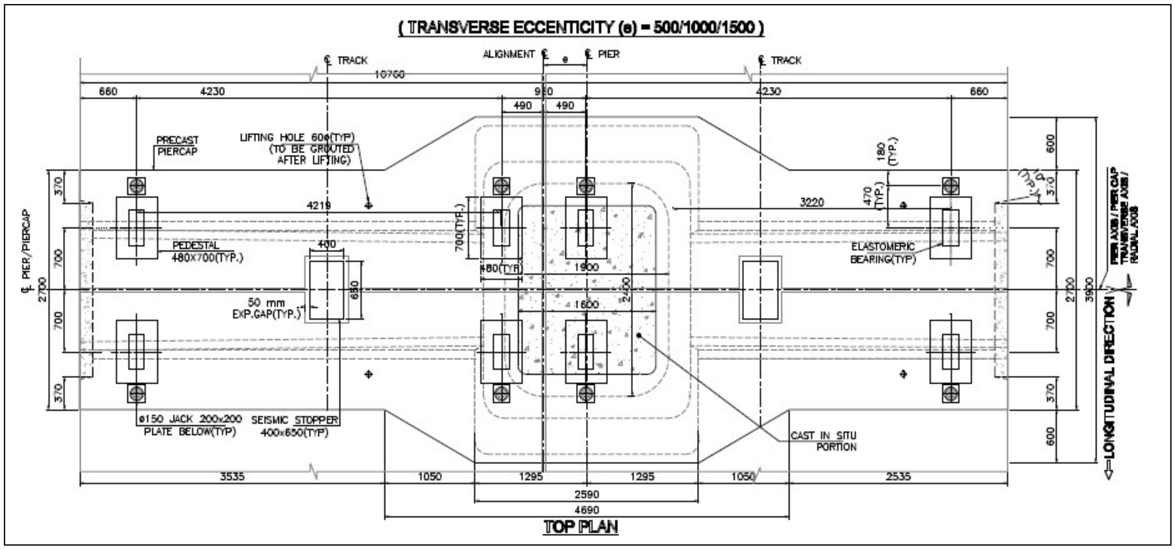

Fig.1 Top Plan of Pier Cap

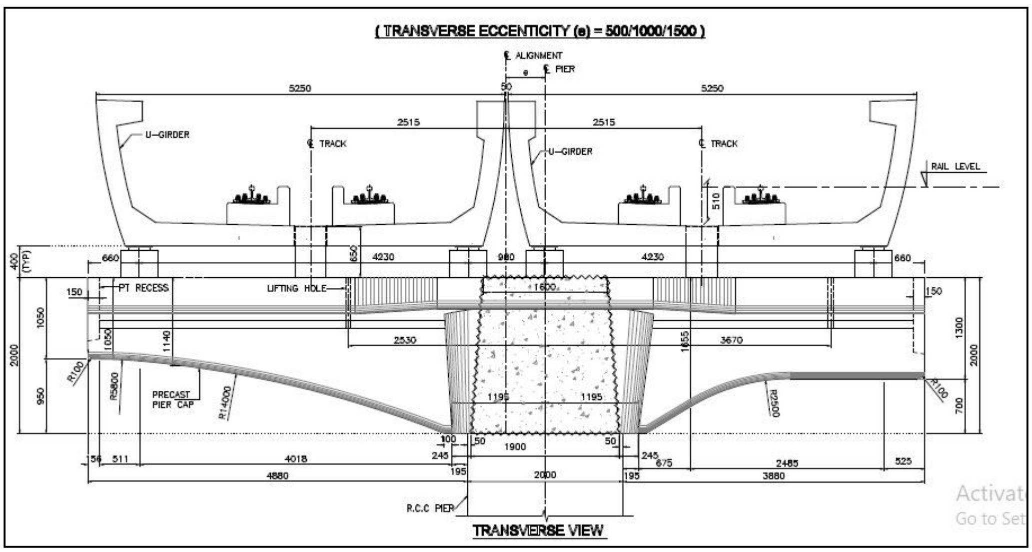

Fig.2 Transverse section of pier cap

4 METHODOLOGY:

The pier cap experiences some critical combination of loads apart from the self-weight and dead load of girders. Live load combinations are also considered from both left and right span of U-girder. Cantilever Pier caps are structural components that have a complex arrangement, nonetheless modelling them is quite simple on MIDAS civil.

The longitudinal moment in the pier cap is by far nullified by the occurrence of the same type and number of U girders on both the sides. The distance from the centre point of the bearing to the face of the pier is the lever arm that is considered in the resulting calculus. In this case, both the spans on either sides of the pier cap have the identical number of girders and spans that almost nullify the longitudinal moment 28m respectively. This leaves us with a considerably less balance of longitudinal moment residual in the pier cap. This residual longitudinal moment acts as torsion in the section of the pier cap. Hence an additional check for torsional moment and a respective torsional reinforcement has to be provided.

The transverse moment is the main design moment for the pier cap. Since the pier cap can be likened to two oppositely protruding cantilever beams ebbing from a common pier, we need to ascertain what side of the cantilever is the side generating the maximum transverse moment. Each of the bearings have a different lever arm and hence an ascending magnitude of moment from the face of the pier on both sides.

The design of a cantilever pier cap primarily revolves around three things:

- Cable Profile Manipulation
- Strand Numbers
- Prestress Activation Stages

In this pier cap, the occurrence of U-girders on either side begs a unique cable profile as the loads differ. Hence this makes our cable profile asymmetric to the central plane. The manipulation of the cable profile depends largely upon the tension generation at the top or bottom fiber in the construction stages and some service load combinations. It has to be ensured that the top or bottom fibers of the cantilever do not cross tensile stress of more than 1N/mm2 and ensured that it experiences a zero tensile stress. The straight profile of the cable is maintained at the central portion of the pier whereas the profile parabolises near the ends as indicated. It is worth noting that the anchors of these cables do not and cannot be superimposed. Hence an anchor block has to be installed at the extreme faces of the cap which maintains an anchor grid. Appropriate offset has to be providing between the grids to allow for the stressing chamber to attach itself to the anchor block.

The reinforcement placed has to cater to the ascending shear force from the pier face out. And the longitudinal reinforcement has to satisfy the minimum reinforcement criteria for every different section that is encountered.

CONCLUSION

In conclusion, prestressed cantilever pier caps play a crucial role in bridge design, providing support and stability to the structure. The use of prestressed concrete in pier caps offers several advantages, including increased strength, durability, and cost-effectiveness.

This review paper has highlighted the importance of prestressed cantilever pier caps in bridge engineering and has discussed various aspects of their design, including factors influencing their design, the effects of eccentricity, and analysis methods for determining prestress forces and losses.

Additionally, the paper has provided an overview of relevant design codes and standards, emphasizing the importance of adhering to these guidelines to ensure the safety and performance of prestressed cantilever pier caps.

Overall, research and advancements in the field of prestressed concrete have contributed to the development of innovative design solutions and improved performance of bridge structures. Further research is needed to address challenges such as the long-term behavior of prestressed concrete and the optimization of design parameters for enhanced efficiency and sustainability.

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