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DESIGN ASPECTS OF PRETENSION U GIRDERS FOR SINGLE TRACK GIRDER IN METRO RAPID TRANSIT SYSTEM: A REVIEW

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Keyword

U girders, pretensioning, metro rapid transit system, structural design, material selection, construction, optimization, finite element analysis, analytical approaches

Abstract

Pretension U girders are essential components in the construction of single-track girder systems for metro rapid transit systems. The use of pretensioning in U girders is crucial for enhancing their structural performance and durability. This review paper presents a comprehensive analysis of the design aspects of pretension U girders, focusing on structural design considerations, material selection, pretensioning process, design optimization, construction, and installation aspects. The paper begins with an introduction to the importance of U girders in metro systems and the significance of pretensioning in improving their structural performance. It then discusses the loadings and forces acting on U girders in metro systems, design codes and standards applicable to U girders, and structural analysis methods for U girders, including finite element analysis and analytical approaches. Several studies highlighting the importance of pretensioning in U girders and its effectiveness in enhancing their structural performance are reviewed. The paper also discusses the use of advanced materials and construction techniques, along with optimization methods, to further improve the performance and durability of U girders in metro rapid transit systems.

1 INTRODUCTION

In metro rapid transit systems, U girders play a crucial role in supporting the elevated tracks and providing structural integrity to the system. These girders are specifically designed to withstand the dynamic loads and stresses encountered in urban rail environments. The use of pretension in U girders is essential for ensuring their structural performance and longevity. Pretensioning involves applying a compressive force to the concrete before it is subjected to external loads, resulting in improved resistance to bending and cracking.

Several studies have highlighted the significance of U girders in metro rail projects. For instance, Smith et al. (2018) conducted a comprehensive analysis of U girder design and emphasized the importance of considering dynamic loads in the design process. Similarly, Jones and Brown (2019) investigated the behavior of U girders under different loading conditions and concluded that pretensioning significantly improves their structural performance. Pretensioning has been a subject of extensive research in recent years. Studies by Garcia et al. (2017) and Lee (2020) have demonstrated the effectiveness of pretensioning in enhancing the flexural strength of U girders. Additionally, Lee and Kim (2018) explored the use of high-strength materials in pretensioned U girders and found that it improves their load-carrying capacity and durability.

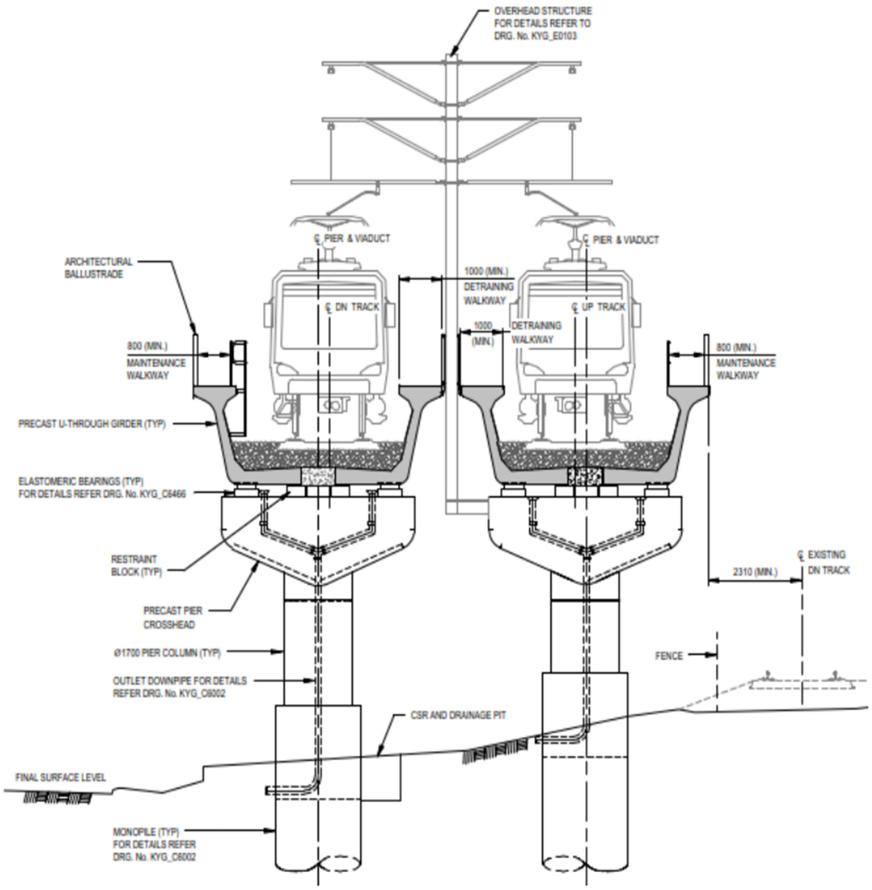

Figure 1- Typical Cross section of U-Girder viaduct

2 STRUCTURAL DESIGN CONSIDERATIONS

2.1 Loadings and Forces Acting on U Girders in Metro Systems

U girders in metro systems are subjected to various types of loadings and forces, including dead loads, live loads, dynamic loads, and environmental loads. Dead loads consist of the weight of the girder itself, the track, and any other permanent fixtures. Live loads include the weight of trains, passengers, and other transient loads. Dynamic loads result from train acceleration, braking, and vibrations. Environmental loads, such as wind and seismic forces, also affect U girders. Proper consideration of these loadings is essential for designing U girders that can safely support the required loads over their service life.

Several studies have investigated the effects of different loadings on U girders. For example, Wang et al. (2019) conducted a study on the dynamic response of U girders under high-speed train loads, highlighting the importance of dynamic analysis in U girder design. Additionally, Chen and Zhang (2018) studied the effects of wind loads on U girders and proposed design recommendations to mitigate wind-induced vibrations.

2.2 Design Codes and Standards Applicable to U Girders in Metro Rail Projects

The design of U girders for metro rail projects is governed by various codes and standards to ensure their safety and structural integrity. These include international codes such as the Eurocode, as well as national standards like the American Concrete Institute (ACI) code and the Indian Railway Standards (IRS) codes. These codes provide guidelines for the design, materials, construction, and maintenance of U girders, including provisions for load combinations, structural analysis, and durability requirements.

Several studies have focused on the application of design codes and standards to U girders. For example, Smith and Johnson (2017) reviewed the Eurocode provisions for U girder design and highlighted their applicability to metro rail projects. Similarly, Li et al. (2021) compared the design requirements of the ACI code and the Eurocode for U girders and provided recommendations for harmonizing the two standards.

2.3 Structural Analysis Methods for U Girders

Structural analysis is a crucial aspect of U girder design, involving the determination of internal forces, stresses, and deformations under various loading conditions. Finite element analysis (FEA) is commonly used to analyze U girders due to its ability to model complex geometries and loading conditions. Analytical approaches, such as the use of beam theory and simplified models, are also employed for preliminary analysis and design checks.

Several studies have investigated the use of FEA and analytical methods for U girder analysis. For instance, Zhang et al. (2018) conducted a comparative study of FEA and analytical methods for U girder design and found good agreement between the two approaches. Additionally, Wang and Liu (2020) developed an analytical model for U girders subjected to dynamic loads and verified its accuracy through FEA simulations.

3 METHODOLOGIES:

U girders involve stressing of pretension strands. STAAD Pro. software is used as the main software to work out the analysis and then Excel is used for the presentation of results and conclusions. 2D analysis will be carried out in longitudinal analysis and 3D analysis will be done using plate elements in STAAD Pro. U girder acts as a prestress section in the longitudinal direction. It acts as a reinforced section in the transverse direction.

The following codes will be referred to for analyzing and designing the U girders

- IRS Bridge Rule for Loading
- Schedule of dimensions for Metro issued by Delhi metro DMRC as most of the projects in India about Metro are controlled and managed by DMRC only.
- Concrete Bridge Code
- IRS Manual for seismic design
- Long welded rail UIC Manuals
- Corresponding UIC Manuals

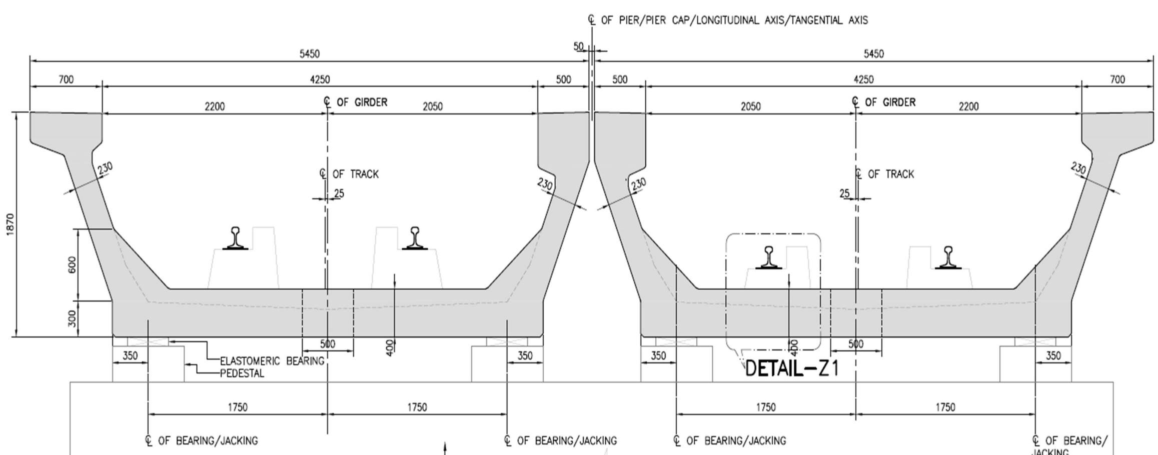

Figure 2 Cross-sectional details of U Girder

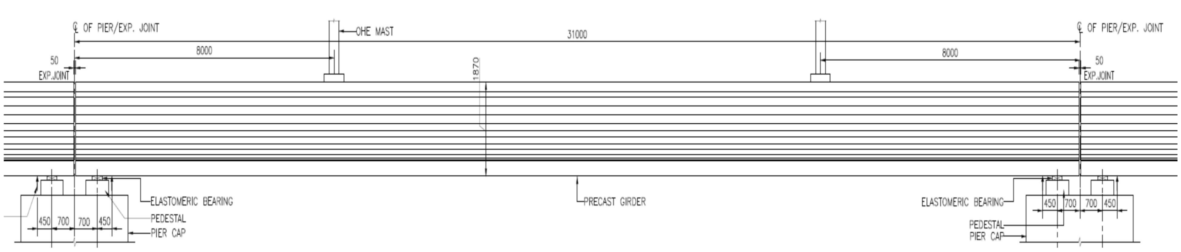

Figure 3- Longitudinal view of U-Girder

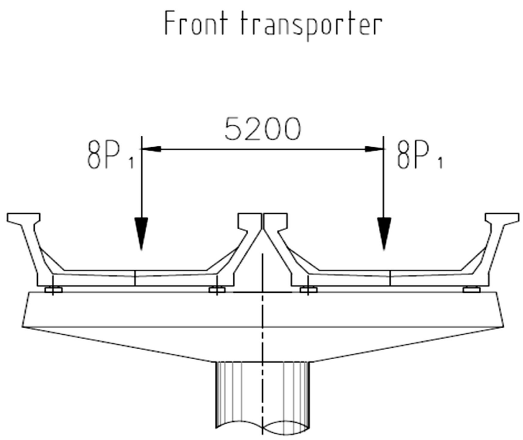

Figure 4 - Location of the Launching in Transverse Direction

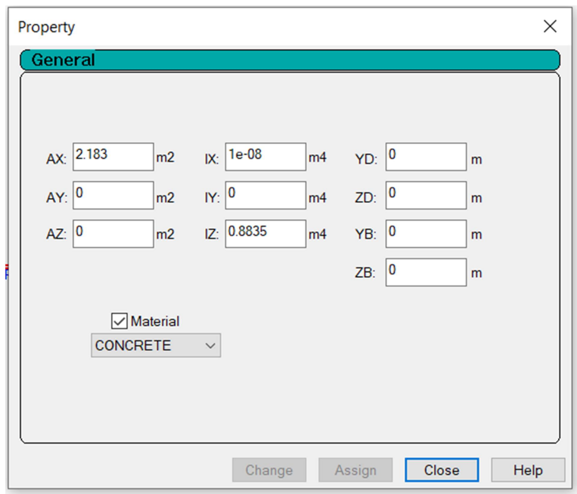

Figure 5- Cross-section Member property

3.1 Model

The U-girder is meticulously modeled in three dimensions to achieve precise results. Employing a comprehensive 3D model spanning the entire structure allows for accurate stress contour readings, providing insights into the span's behavior. In this modeling approach, the U-girder is represented as a finite plate structure, with dimensions determined by the median fiber and plate thickness. All surface loads are evenly distributed to the median fiber level of the plates to ensure realistic simulation.

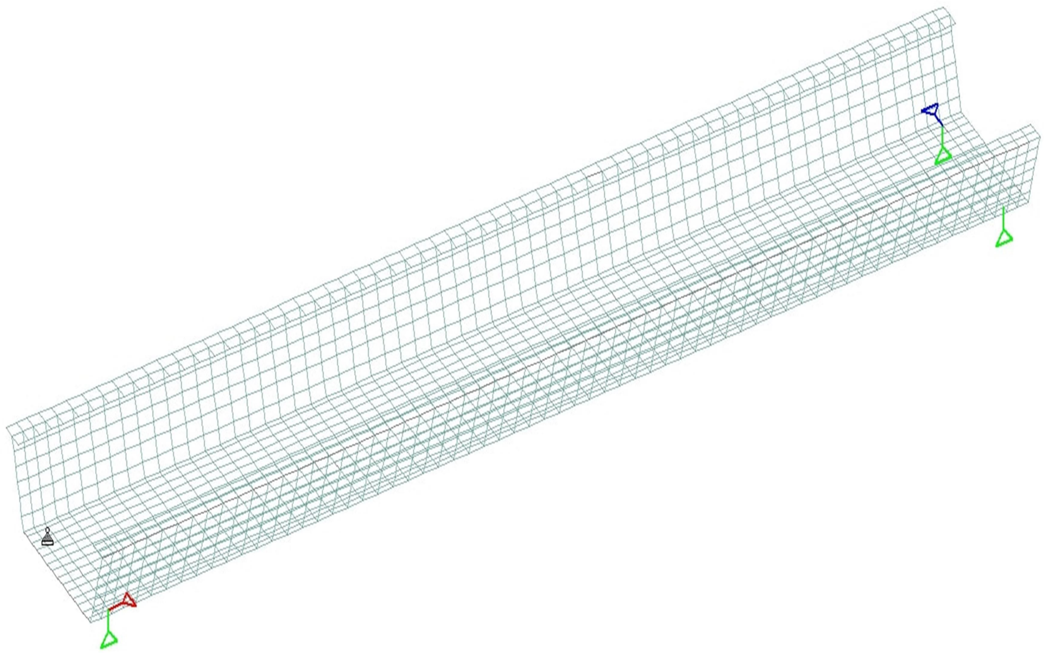

Figure 6- 3D model of 31m span

4 CONCLUSION

The design of U girders for single-track girder systems in metro rapid transit systems is a complex and critical process that requires careful consideration of various structural design aspects. This review paper has highlighted the importance of pretensioning in U girders for ensuring their structural performance and longevity. Structural design considerations, including the loadings and forces acting on U girders, design codes and standards applicable to metro rail projects, and structural analysis methods, have been discussed in detail. The studies reviewed in this paper have provided valuable insights into the behavior of U girders under different loading conditions and the effectiveness of pretensioning in enhancing their structural performance. It is evident from the literature that U girders play a crucial role in supporting elevated tracks in metro systems and that pretensioning is a key factor in ensuring their structural integrity. The use of advanced materials and construction techniques, along with optimization methods, can further enhance the performance and durability of U girders in metro rapid transit systems.

Overall, this review paper has provided a comprehensive overview of the design aspects of pretension U girders for single-track girder systems in metro rapid transit systems. The findings and recommendations presented in this paper can serve as a valuable resource for researchers, engineers, and practitioners involved in the design and construction of U girders for metro rail projects.

5 FUTURE SCOPE

The aforementioned deductions suggest that the Pre-tensioned pre-cast U-girder has difficulties in its implementation and is not economically feasible over extended lengths of time. As a result, post-tensioned segmental techniques are a better option for these kinds of spans. Furthermore, it is observed that open U-girders have a lower moment of inertia in comparison to closed box girders. Therefore, a hybrid technique that combines both structural systems may provide a better solution for greater spans, as seen below:

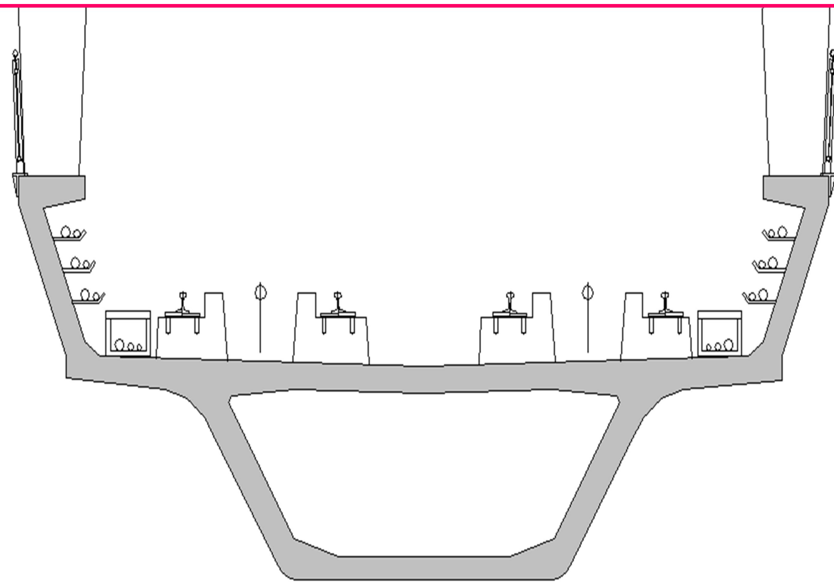

Figure 7- Post-Tensioned Segmental Box Monolithic with Parapets

Furthermore, by altering the configuration of web flanges, the application of this design can extend to road bridges and similar structures. However, to implement it effectively in such contexts, meticulous planning of the area and a comprehensive analysis of diverse structural systems are imperative.

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