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COMPARATIVE ANALYSIS OF U-GIRDERS AND CONVENTIONAL PSC I GIRDERS FOR METRO RAPID TRANSIT SYSTEMS: A COST AND STRUCTURAL EFFICIENCY PERSPECTIVE

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ABSTRACT

This paper presents a comparative analysis of U-Girders and conventional PSC I Girders for their suitability in Metro Rapid Transit Systems. The objective of the study is to assess the cost-effectiveness and structural efficiency of U-Girders in comparison to conventional PSC I Girders. Through detailed calculations and evaluations, various aspects including material usage, construction costs, and structural advantages are examined.

The study finds that U-Girders demonstrate superior efficiency in material utilization, with significant reductions in concrete, steel, and HTS consumption compared to conventional PSC I Girders. This efficiency translates into substantial cost savings, exceeding 20% of the overall project cost. Furthermore, the unique shape of U-Girders eliminates the need for additional parapets, simplifying construction processes and reducing construction complications.

Keyword Metro Rapid Transit Systems, Comparative Analysis, Cost-effectiveness, Structural Efficiency, Material Utilization, Construction Costs

INTRODUCTION

Metro rapid transit systems play a pivotal role in urban transportation infrastructure, offering efficient and sustainable mobility solutions for densely populated areas. The design and construction of infrastructure components for such systems require careful consideration to ensure safety, reliability, and cost-effectiveness. Among these components, girders serve as essential elements in supporting tracks and facilitating smooth train operations. In recent years, U-Girders have emerged as a promising alternative to conventional PSC I Girders, particularly in single-track configurations, due to their unique structural design and potential cost savings.

This paper aims to explore the design aspects of U-Girders specifically tailored for single-track applications in metro rapid transit systems. By conducting a comparative analysis between U-Girders and conventional PSC I Girders, the study seeks to evaluate their respective advantages and disadvantages in terms of cost, material utilization, and structural efficiency. Through a comprehensive examination of construction complications and design considerations, the paper aims to provide insights into the suitability of U-Girders for metro rapid transit infrastructure projects.

The analysis presented in this paper draws upon relevant literature and industry standards to provide a comprehensive understanding of the design and construction challenges associated with U-Girders. By synthesizing existing research findings and practical insights, this study aims to contribute to the body of knowledge surrounding metro rapid transit infrastructure design, with a specific focus on the role of U-Girders in optimizing project costs and enhancing structural performance.

LITERATURE REVIEW

Metro rapid transit systems are crucial components of urban transportation networks, providing efficient and sustainable mobility solutions for urban residents. The design and construction of infrastructure for such systems require careful consideration to ensure safety, reliability, and cost-effectiveness. Among the key structural elements, girders play a critical role in supporting tracks and accommodating various loads associated with train operations. In recent years, there has been increasing interest in exploring alternative girder designs, particularly U-Girders, for their potential to improve construction efficiency and reduce costs in metro rapid transit projects.

Several studies have investigated the structural behavior and performance of U-Girders compared to conventional PSC I Girders in the context of metro rapid transit systems. Cho (2018) conducted a comparative study on the structural behavior of pretensioned I and U girders for metro bridge decks. The study found that U-Girders offer comparable structural performance while potentially reducing construction costs and simplifying construction processes.

Park and Park (2019) focused on the optimization of U-Girder bridge design, considering the dynamic characteristics of metro trains. Their study highlighted the importance of optimizing girder designs to enhance structural performance and ensure safety under dynamic loading conditions.

Cost analysis has been another area of interest in evaluating the feasibility of U-Girders for metro rapid transit projects. Ramli and Kassim (2017) conducted a cost analysis comparing precast pretensioned I-Girders and U-Girders for long-span bridges. Their analysis revealed potential cost savings associated with the use of U-Girders due to reduced material usage and simplified construction processes.

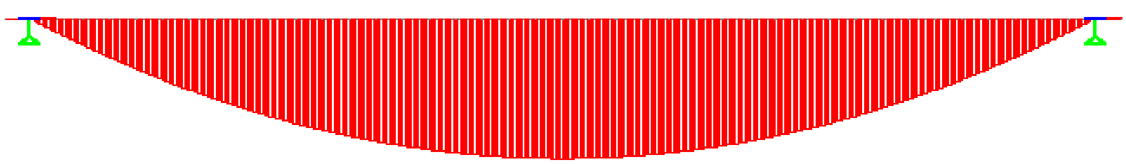
Guidance documents such as the Transit Cooperative Research Program's "Guidebook for the Design of Prestressed Concrete Girders for Long-Span Metro Structures" provide valuable insights into design considerations and best practices for incorporating U-Girders in metro rapid transit projects (Transit Cooperative Research Program, 2014).

Recent research has also focused on structural optimization and application development of U-Girders in urban rail transit engineering. Wei and Zhao (2021) conducted structural optimization design of U-shaped concrete girders, emphasizing the importance of considering various design parameters to enhance structural efficiency and performance.

Overall, the literature highlights the potential of U-Girders to offer cost-effective and structurally efficient solutions for metro rapid transit infrastructure. However, further research is needed to explore additional aspects such as long-term durability, maintenance requirements, and environmental impact to fully assess the suitability of U-Girders for metro rapid transit systems.

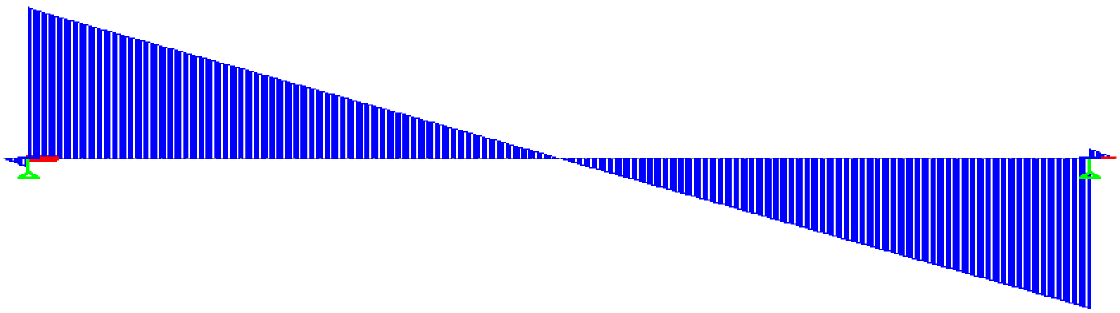
RESULT AND DISCUSSION

Bending Moment due to self-weight for 31m overall and 29.6m centre to centre of bearings



BM max	5960	kNm

Shear force due to Self-weight for 31m overall and 29.6m centre to centre of bearings



SF Max = 813 kN

Figure 1 BM & SF diagram due to self-weight.

Resuts from Staad Pro :

Below result extracted from the STAAD pro model without load factor

Table 1: *Untutored BM and SF*

Node No.	Dist from EJ	Girder Self-weight		Super Imposed Load		Live load (EUDL-BM)	Live load (EUDL-SF)	Launching Girder load	Girder SW-Lifting condition (BM)
		BM	SF	BM	SF	BM	SF	Max. BM	
1	0.000	0	0	0	0	0	0	0	0
2	0.700	-17.4	813	-8	457	-10	657	53	-17
3	1.440	566	767	322	434	406	624	429	-78
4	2.180	1119	727	635	412	800	591	832	429
5	2.920	1642	687	932	389	1172	559	1221	952
6	3.660	2135	646	1211	366	1524	526	1577	1445
7	4.400	2598	606	1473	343	1854	493	1916	1908
8	5.140	3032	565	1718	320	2162	460	2237	2342
9	5.880	3435	525	1947	297	2450	427	2528	2745
10	6.620	3809	485	2158	274	2716	394	2807	3119
11	7.360	4152	444	2353	252	2961	361	3057	3463
12	8.100	4466	404	2531	229	3185	329	3285	3776
13	8.840	4750	363	2691	206	3387	296	3495	4060
14	9.580	5004	323	2835	183	3568	263	3683	4314
15	10.320	5228	283	2962	160	3728	230	3842	4538
16	11.060	5422	242	3072	137	3866	197	3990	4733
17	11.800	5587	202	3165	114	3983	164	4106	4897
18	12.540	5721	162	3241	91	4079	131	4206	5032
19	13.280	5826	121	3301	69	4153	99	4288	5136
20	14.020	5901	81	3343	46	4207	66	4337	5211
21	14.760	5945	40	3368	23	4239	33	4372	5256
22	15.500	5960	0	3377	0	4249	0	4380	5271

The above unfatored BM and SF values are taken for further calculation and various load combinations of ULS and SLS are per IRS CBC and factored BM and SF for each combination is derived and taken for the Design calculation. As per the losses in pretension and factored BM in SLS combination the design calculation is carried out and No of pretension strands has been worked out in each 22 interval.

The pretension strands have uniform ecentricity at each location since they are straight in nature the length of the debond needs to work out otherwise U-Girder may compress at both ends due to prestressing force.

This debonding length shall be a workout from equating external BM due to self-weight, SIDL, LL, and other external load and BM due to the prestressing force at each location, and curtailment shall be done.

The figure below shows showing curtailment of the pretension stand.

Location from EJ (m)	Strands Bonded	Nos	Unbonded	Nos
Mid span	1 to 92	92	-	0
6.4	1 to 11 & 36 to 92	68	12 to 35	24
4	1 to 5, 42 to 64, 75 to 92	46	6 to 41, 65 to 74	46
2.5	1 to 4, 43 to 57 & 82 to 92	30	5 to 42, 58 to 64 & 75 to 81	62
1.44	1 to 4, 43 to 46, 47 to 50 & 89 to 92	16	5 to 42, 5 to 88	76

Table 2: *Schedule of No of strand*

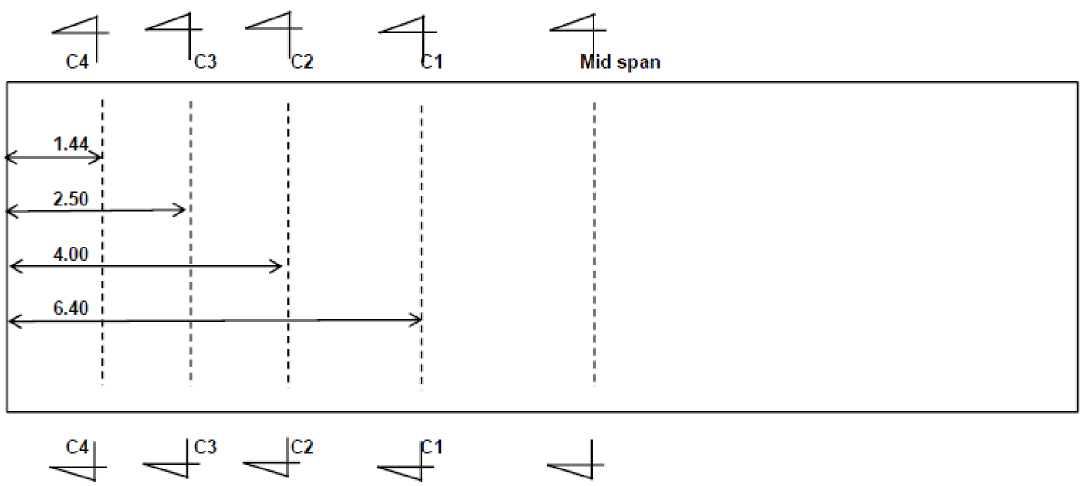


Figure 2 *Curtailment of pretension stand.*

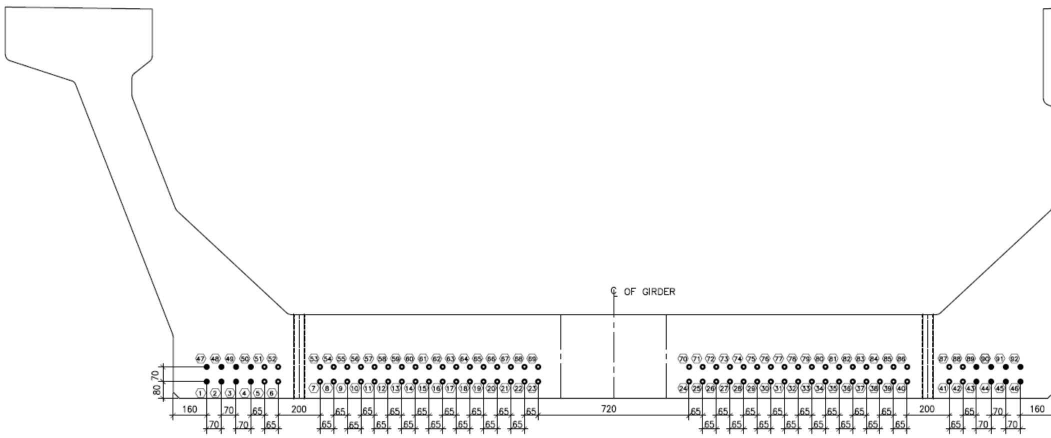


Figure 3 *Cross section showing the arrangement of the pretension Strand.*

CONCLUSIONS

The conclusions drawn from the comparison between U-Girders and conventional PSC I Girders for the Metro Rapid Transit System are significant:

- **Efficiency in Material Usage:** U-Girders demonstrate superior efficiency in material usage compared to conventional PSC I Girders. With a concrete utilization rate of 66%, steel utilization rate of 84%, and HTS utilization rate of 43%, U-Girders offer substantial savings in both concrete and steel.
- **Reduction in Construction Costs:** The reduction in material usage directly translates to cost savings in construction projects. The analysis suggests that the overall cost of the project can be reduced by more than 20% when using U-Girders instead of conventional PSC I Girders.
- **Structural Advantages:** U-Girders offer structural advantages due to their unique shape, which eliminates the need for extra parapets to support overhead equipment (OHE) masts and walkways. This streamlined design contributes to simplified construction processes and reduced construction complications.
- **Reduction in Superstructure Weight:** The reduced weight of the superstructure results in smaller foundation sizes and shorter approach lengths. This not only reduces construction costs but also minimizes environmental impact and improves overall project sustainability.

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