Industrial Engineering Journal
ISSN: 0970-2555
Volume : 53, Issue 10, No.2, October : 2024

A REVIEW ON DESIGN AND ANALYSIS OF SUPERSTRUCTURE OF POST-TENSION PSC I-GIRDER BRIDGE

Adilhusan H. Kadiwala, Research scholar, Civil Engineering Department, PIET, Parul University, Vadodara.
Dr. Vrajesh M Patel, Assistant Professor, Civil Engineering Department, PIET, Parul University, Vadodara.

ABSTRACT:-
Bridges are architectural marvels designed to facilitate movement over obstacles without obstructing the space below. Nowadays, the preferred choice for spanning distances of 20 to 50 meters is the PSC I-Girder Bridge. Post-tensioning techniques, commonly utilized in bridge construction, have made prestressed bridges, particularly post-tensioned ones, predominantly [6].This work focuses on the detailed economic design aspects of a PSC I-Girder Bridge.

KEYWORDS:
Prestressing, PSC I-Girder, Cable profile, moving load.

I.INTRODUCTION:

Over the last three decades, significant progress in the field of bridge engineering has led to the widespread adoption of several innovative reinforced and prestressed concrete bridge decks. These decks not only demonstrate structural efficiency and aesthetic appeal but also offer cost-effective solutions that cater to the demands of high-speed highway traffic. Beam and girder bridges represent the simplest forms of bridge spans, each supported by an abutment or pier at either end. More intricate beam bridges are constructed by aligning multiple beams closely with a deck extending across their tops. In girder bridges, the beams serve as the primary support for the deck, facilitating the transfer of loads to the foundation. These bridge designs, known as simply supported, do not transfer any moments throughout the support structure. While a basic beam bridge could be as rudimentary as a log or a wooden plank placed over a stream, modern infrastructure demands bridges built from steel, reinforced concrete, or a combination of both materials. As concrete tends to be robust in compression but weak in tension, reinforcement methods like prestressing and post-tensioning using high-strength steel tendons are employed to enhance its strength and durability. Post-tensioning, in particular, allows for the creation of structures with minimal deflection and cracking under full load, enabling longer spans, lighter weight, and reduced concrete usage without sacrificing structural integrity.

II.LITERATURE REVIEW

Avinash Kumar Vidyarthi, Dr. P. K. Singhai, Rohit Sahu (2021)[1] In this research work they have study that the straight and parabolic tendon profile was created for the four cell prestressed girder and study on the effect of eccentricity, Prestressing force and Cable profile. From results the straight tendon profile produces more stress at top and the shear force is also greater than parabolic tendon profile. Based on load balancing concept for uniformly distributed loads the parabolic tendon profile reduces the stresses than straight tendon profile.. The deflection due to the application of live load at critical section is 7.5 mm for straight tendon profile and 7.06mm for parabolic tendon profile. Stress due to loads at critical section for parabolic profile is 1.745 N/mm2 and for straight cable profile 9.217 N/mm2.

M.P.Chodhary and S.S.Sanghai (2021) [2] In this work they analysed for box girder, line model is in Staad pro, whereas for I-girder, grillage model analysed. Results tabulated shows that at different section of each girder, Values of bending moment changes the difference between the bending moments at every section Of girder is not so high, hence a cable profile should also be Smooth in nature at every point of girder. They also found that the for same dimensions and cross section, if Design is done by WSM method it consumes more steel which Using LSM becomes more effective.

Bhagyashree C Jagtap, Prof. Mohd. Shahezad (2016) [3] According to the findings of the research, prestressed concrete girders prove to be a more cost-effective choice compared to plate girders. The cost of construction increases as the span length grows. In terms of longevity, prestressed concrete girders outperform steel plate girders. In summary, for spans under 15m, steel plate girders are recommended. Spans ranging from 15m to 36m require consideration of additional project factors. However, for spans exceeding 24m, prestressed concrete girders clearly offer a superior alternative to steel plate girders, especially beyond 25m due to cost concerns.

V.N.L.S.A.P.Aishwarya, Yamin Srevalli,M.Neelakantam(2019)[4] In this research, detailed design for I girder and box girder were explained. Comparative analysis was Done and economical section was selected for substructure design. For the particular span, different criteria are adopted to select a suitable girder for a superstructure like, site Conditions, ease of materials, etc. I Girder and box girder are the most commonly used section for medium to large span PSC bridges. From the analytical study, I girders are mostly used sections due to higher stability than the box girder due To the closed section. Box girders are generally useful where spans having curves to avoid distortion and Warping. However, sections are chosen depending upon the quantity of materials used for the particular span which is Again based upon the number of girders per span. This is due to the simple reason that, when the width of Slab increases more number of longitudinal girders are required resulting in reduction of stiffness of beams In transverse direction.From the comparative analysis, I girder resulted in economic section than the box girder, by less quantity of Steel than the box section. Quantity of concrete being comparatively equal for both the girders, I girder is Chosen as economical section for the design of substructure. Substructure design was carried out using developed excel sheets whose reactions were obtained from the Analytical results of superstructure. Subsequently, suitable design for foundation shall be carried out.

S.Rana,R.Ahsan,S.N.Ghani,(2019)[5] In this research design obtained by the optimization approach Is 35% more economical than the existing design of the real life project. Girder spacing is greater in the optimum design so the number of girders In the bridge obtained in the optimal design is less than that of the existing design. In the cost optimum Design girder depth, top flange width, bottom flange thickness and slab thickness are comparatively Greater and top flange thickness, bottom flange width, web width, prestressing steel and deck slab reinforcement are lesser than the existing design.

Bhawar P.D.,Wakchaure M.R.,Nagare P.N (2015)[6]The research shows that through the integration of optimization techniques with traditional design methods, it is possible to lower the overall cost of the structure while maintaining its stability. The goal is to determine an appropriate design that not only meets the functional and technical specifications of the post-tensioned I girder but also reflects the best choice among a range of acceptable design options, each based on different assumptions and parameters.

Prakash D. Mantur ,Dr.S.S.Bhavikatti**,**(2017)[7] The research suggested that to enhance PSC I-girder design, a sequential linear programming approach with an enhanced move limit method is applied. The choice of concrete grade, ranging from M30 to M60, is suggested based on the span length, rather than being significantly affected by the cost ratio within 50-100.

Narendra Singh, Dr. Savita Maru (2023)[8] In this research shows that the as the span of a bridge increases, the natural time period also sees an increase while the natural frequency decreases. Notably, the natural time period for a box girder bridge surpasses that of an I girder bridge, with a 9.55% difference observed for a 30-meter span. The base shear, too, escalates with a wider span, particularly more pronounced in the Y direction compared to the X direction. For instance, for a 30-meter span, the base shear of a box girder exceeds the PSC I girder bridge by 10.62%. Furthermore, the displacement at the top of the bent cap escalates as the span widens, with box girder bridges exhibiting higher displacement rates compared to precast I girder bridges. A 9.55% disparity in displacement at the top of the bent cap is noted for a 30-meter span between the two bridge types. Interestingly, the

displacement in the X direction supersedes that in the Y direction for both box girder and I girder bridges. Additionally, the moment induced by various loads, such as dead loads and live loads, is significantly higher in box girder bridges compared to I girder bridges. This is due to the cumulative effect of increasing the bridge span, which amplifies the forces acting on the girders owing to the heightened mass of the superstructure.
Soumya Suhreed Das, Joyonta Chandra Das, MD.Sifur Rahman,(2024)[9]In this research prestressed concrete I-girder bridge was designed, modelled and analysed for seismic activity using CSiBridge, a software based on finite element. The practical observations aligned well with theoretical predictions and other established theories regarding how structures respond dynamically to random cyclic loads. Research results have confirmed that using pre-stressing forces can effectively reduce vibrations and improve stability in the face of dynamic loads, contrasting with scenarios without pre-stress. It has been highlighted that certain critical factors in design optimization, such as support type, number, and placement, along with steel reinforcement ratios, are pivotal in determining how structures behave under dynamic forces. These factors significantly impact stress levels in vital structural elements or areas. Balancing the stiffness of bearings is crucial in achieving preferred modal responses for such bridges during seismic events. Only lowering damping levels might not lead to substantial enhancements in vibroacoustic characteristics.Distribution factors for loads were computed to assess bending moments and shear forces at critical segments prior to developing a bridge model. By evaluating bending and shear values in-depth, the necessary quantity of girders' strands was determined, taking into consideration both bending moments and shear forces.
Devashree Sawant,N.G.Gore,P.J.Salunke (2024)[15] The research shows that the optimization of the minimum cost design for PSC I-Girder can be achieved by using the interior penalty function method, allowing for significant cost savings compared to traditional designs. The extent of these savings depends on factors like slab span and material grade. Notably, a savings of up to 11.68% can be realized for a 20m span PSC I-Girder made of M50 grade concrete. Deeper girders result in decreased PSC I-Girder costs, and using M50 concrete with M20/Fe415 material for shorter spans can be more economical. Additionally, 12.7mm diameter strands are more cost-effective than 15.2mm strands.
Olivier BURDET, Mare BADOUX (2000))[17] In this research they have done Analysis of a standard box girder highway bridge's double design shows that the differences between solutions using internal and external tendons are less significant than initially expected. In cases of shorter spans or shallower cross-sections (under 3 meters), internal tendons require less passive and prestressed reinforcement. On the other hand, for deeper cross-sections, external tendons need less reinforcement. Despite the drawback of not fully utilizing the tendon load capacity under extreme conditions, external tendon solutions can still be competitive in terms of reinforcement needs. In practical scenarios, variations in prestressing levels between internal and external solutions are minimal. Hence, decisions should not hinge on prestressing amounts but rather on the specific advantages of each prestressing approach.
Mohamad Aldi Ramdani, Nabila Puteri Widiya ,Ambar Susanto ,Yackob Astor (2020)[18] The research shows that They have examine and assessment of the Leuwigajah Bridge, featuring a 47-meter span and 10-meter width utilizing a PCI-Girder H210 with pre-stressed concrete, the structural evaluations yielded insights into the reinforcement patterns and their respective spacing. Additionally, the analysis of the pre-stressed concrete girder highlighted the necessity for 6 tendons and 110 strands, factoring in a 25.059% loss of pre-stressing. Employing Building Information Modelling (BIM) technology, along with 3D modelling, for the planning and evaluation of the Leuwigajah Bridge can enhance effectiveness and efficiency by providing a more precise and lifelike representation of the bridge design, aiding in the early identification and prevention of potential issues. The integration of BIM into the bridge's design can streamline project management, ultimately reducing production expenses. By visually modelling each bridge component in 3D against the actual environmental conditions, the likelihood of design flaws can be minimized, ensuring a smoother project execution process. Leveraging Tekla Structures software for 3D modelling allows for a comprehensive depiction of bridge elements and precise reinforcement details derived from structural calculations, leading to

time and cost savings, as well as simplifying the overall design and construction phases. Employing Infraworks software for modelling existing bridges, including the Leuwigajah Bridge, enables stakeholders to envision the completed bridge within its real-world context, fostering a deeper comprehension of the final design aesthetics.
Shubham Landge, Umesh Bhagat, Shubham Bhaisare, Ved Prakash, Dr. I. P. Khedikar,(2018)[20] In this research analysis involves studying precast pre-stressed concrete girder bridges with a 28-meter length. In all scenarios, deflection and stresses remain acceptable. The use of this design demonstrates its efficiency by keeping major design parameters like serviceability, deflection, and shear well within limits, faring better than the traditional deck slab design. Enhancing the precast pre-stressed concrete girder configuration with pre/post tensioning can lead to even more favourable outcomes. The simplicity in applying pre-stressing force and calculating jacking force sets it apart from the ordinary design, which demands a composite approach for incorporating pre-stressing. The traditional deck slab design poses challenges in maintenance and serviceability due to its higher number of exposed components, a problem easily resolved by adopting the precast pre-stressed concrete girder deck slab configuration.

III. CONCLUSION:

The main aim of the study was to learn and understand the Concept of analysis and design of post-tensioned PSC I-Girder Bridges. From the results And comparison, following points are concluded:-

- A comparative examination was conducted on various bridge sections such as I-girders and box-girders, along with diverse cable profiles. Different prestressing materials were utilized, and analysis was carried out using various codes and software tools like CSI Bridge and STADD Pro.
- The bridges were analysed using various models, including the development of a 3D finite element model through multiple software tools.
- Examination has been conducted on the behavioural robustness, flexibility, and additional characteristics of the cost-efficient segment alongside an optional segment.
- By adjusting the section’s depth, a detailed examination was conducted to determine the most cost-effective construction methods.

Reference:-

1. Avinash Kumar Vidyarthi,Dr.P.K.Singhai,Rohit Sahu, October 2021,“Analysis of prestressed concrete girder for bridges” International journal of Trend in scientific research and development.
2. M.P.Choudhary,S.S.Sanghai, May 2019, “Pre-stressed concrete bridge girder analysis and design ” Global Journal for research analysis.
3. Bhagyashree C Jagtap,Prof.Mohd.Shahezad, January-February 2016, “Comparative study of prestressed concrete girder and steel plate girder for roadway over bridge” International journal of Scientific research in science, Engineering and Technology.
4. V.N.L.S.A.P.Aishwarya, Yamin Srevalli,M.Neelakantam,2019, “Comparative study on I girder and box girder for design of psc bridge” International conference on sustainable environment and civil engineering.
5. S.Rana,R.Ahsan,S.N.Ghani, August 2010, “Design of prestressed concrete I-girder bridge superstructure using optimization algorithm ”IABSE-JSCE Joint conference on Advances in bridge Engineering-II.
6. Bhawar P.D.,Wakchaure M.R.,Nagare P.N., March 2015, “Optimization of prestressed concrete girder” International journal of research in engineering and technology.
7. Prakash D. Mantur ,Dr.S.S.Bhavikatti, August 2017, “Optimization of precast post-tensioned concrete I-girder bridge” International Research journal of engineering and technology.
8. Narendra Singh,Dr.Savita Maru, March-2023 , “Seismic behaviour PSC box girder and psc precast I girder bridge” International journal for Research in applied science and engineering technology.

9. Soumya Suhreed Das, Joyonta Chandra Das, MD.Sifur Rahman, April-2024, “Dynamic Analysis of pre-stressed concrete girder bridge using csibridge software”, Research Square.
10. Sung-Wan Kim,Da-Woon Yun,Dong-Uk Park,Sung-jin Chang,Jae-Bong Park, November-2021, “Estimation of live load distribution factor for a PSC I bridge in an Ambient vibration test”, Applied science.
11. Chun S. Cai. Mohsen Shahawy, January- February 2004, “Predicted and Measured Performance of Prestressed Concrete Bridges” journal of bridge engineering.
12. Zasiah Tafheem, Nazmus Sakib,K.M.Amanat, August 2010, “Seismic analysis of a three-span deck girder bridge” IABSE-JSCE Joint Conference on Advances in Bridge Engineering-II.
13. Viktor Sigrist, Anja Bäurich, May 2006 , “The development of form In Prestressed Concrete Bridge designs” , International Conference on bridges.
14. Darlina Tanjung, March 2022, “The Main Structure of the Prestress Bridge: Ultimate Calculation Analysis Using Bridge Management System (BMS 1992) Planning Method” , International journal of research and review.
15. Devashree Sawant,N.G.Gore,P.J.Salunke, March 2024 , “Minimum Cost Design of PSC Post-Tensioned I-Girder for Short to Medium Span Bridges” ,International journal of recent technology and Engineering.
16. B. Täljsten, B. Paulsson, C. Popescu,N. Bagge,R. Nilforoush, M. Emborg, Th. Blanksvärd,G. Sas, L. Elfgren, October 2020 , “Assessment of prestressed concrete Bridges challenges” , synergy of culture and civil Engineering-History and challenges
17. Olivier BURDET, Mare BADOUX , 2000 , “Comparison of Internal and External Prestressing for Typical Highway Bridges” , 16TH Congress of IABSE,LUCERE,2000.
18. Mohamad Aldi Ramdani , Nabila Puteri Widiya ,Ambar Susanto ,Yackob Astor , 2020 , “Design of The Prestressed Concrete Bridge Structure On The Leuwigajah Bridge” , Advances in Engineering Research.
19. Phani Ram Gollapudi , Satish Kumar Brahmalla, March 2024 , “Design Details of Post-Tensioned Concrete Bridge Girder, Sustainability And Resilience Score” , International Research Journal of Engineering and Technology (IRJET).
20. Shubham Landge, Umesh Bhagat, Shubham Bhaisare, Ved Prakash, Dr. I. P. Khedikar, May 2018, “Analysis and Design of Pre-stressed Concrete I-Girder Bridge” , International Research Journal of Engineering and Technology (IRJET).
21. M Jagandatta, G Yaswanth Kumar, S Suresh Kumar, 2021 , “Analysis and Design of Composite Single Span Psc-I Girder Bridge Using Midas Civil” , IOP Conf. Series: Earth and Environmental Science 982.