Analysis and Design of Bow String Bridge from Gothuruth to Chathedom Across Periyar River

Parvathy nair A S*
Department of Civil Engineering
Bishop Jerome Institute
Kollam, India
Parvathynair208@gmail.com

Goving Ganesh
Department of Civil Engineering
Bishop Jerome Institute
Kollam, India
govindganeshg7@gmail.com

Arjun P
Department of Civil Engineering
Bishop Jerome Institute
Kollam, India
arjunpradeep194@gmail.com

Devaganga S
Department of Civil Engineering
Bishop Jerome Institute
Kollam, India
devagangas13@gmail.com

Sr. Sobhana
Assistant Professor
Dept. of Civil Engineering
Bishop Jerome Institute
Kollam, India
dhashanamerry4@gmail.com

* Corresponding author
doi: https://doi.org/10.21467/proceedings.7.8.7

ABSTRACT

This project presents the design and analysis of a proposed bowstring bridge connecting Gothuruth to Chathedom across the Periyar River in Kerala. Aimed at enhancing connectivity and regional development, the bridge spans 580 meters with an 11-meter-wide carriageway and 1.2-meter pedestrian paths on both sides. Finite element analysis was used to evaluate structural performance under various load combinations, including wind and seismic forces. The design incorporates high-strength concrete for piers and prestressed steel cables for the arch, ensuring strength and durability. The structure is designed to withstand wind speeds up to 200 km/h and has an estimated lifespan of 50 years. Environmental impact assessments confirm minimal disruption to river flow and aquatic life. Overall, the project offers a sustainable, resilient, and efficient solution for river-crossing infrastructure.

Keywords: bowstring bridge, design, Midas civil, analysis, AutoCAD, Sketchup

I. INTRODUCTION

The proposed bowstring arch bridge from Gothuruth to Chathedom across the Periyar River aims to address the region's growing transportation demands by providing a direct, reliable connection. Currently, the absence of a permanent bridge forces commuters and goods vehicles to depend on longer routes or seasonal ferries, leading to delays, congestion, and increased costs. This project focuses on the structural analysis and design of a bowstring arch bridge, chosen for its efficiency, durability, and minimal impact on the river flow. The design process includes load analysis, material selection, and technical detailing to ensure a safe and sustainable solution tailored to the area's environmental and logistical needs. This project presents the analysis, design, and comparison of two bowstring bridge configurations—vertical hanger and crosstie—for a proposed span across the Periyar River between Gothuruth and Chathedom. Based on structural behaviour under various loading conditions, the vertical hanger bridge proved more viable due to its simpler design and effective load transfer. A scaled physical model aided in visualizing the bridge's real-world response. The design, focused primarily on the superstructure, was executed using MIDAS Civil, AutoCAD, SketchUp, and Lumion. Although foundation design was not covered, the study provides a solid framework for bridge selection. Future work should address the substructure for a comprehensive design.

II. LITERATURE REVIEW

Recent studies emphasize the growing importance of dynamic analysis in the design and evaluation of bowstring arch bridges. Kong et al. [1] conducted a dynamic analysis comparing multiple-arch bowstring bridges to conventional arches, demonstrating that the former exhibit superior load distribution and reduced deflection due to their unique geometry. This study also highlighted how vehicle speed and weight can influence resonance effects, suggesting the need for optimized bracing and damping systems. Sangtiani et al. [2] further explored

Proceedings DOI: 10.21467/proceedings.7.8; Series: AIJR Proceedings; ISSN: 2582-3922; ISBN: 978-81-989164-8-8

structural performance by analyzing different design parameters and bracing configurations, underscoring how span length, material choice, and bracing types significantly affect stability. Greco et al. [3] investigated instability phenomena in tied-arch bridges, focusing on buckling and vibration issues that arise from material fatigue or external loads, and recommended mitigation through enhanced bracing and material selection. More recent research by Akram et al. [4] and Aamir [10] delved into the structural response of bowstring arch bridges under blast loading. Both studies employed finite element analysis to simulate explosion scenarios and identified critical vulnerabilities, particularly at mid-span regions and connection points. These findings call for the integration of blast resistance and dynamic loading considerations into bridge design.

In addition, Gollapudi and Vidhatha [5] examined how rise-span ratio and different hanger configurations influence the stress behavior and deflection characteristics of bowstring arches. Koshi and Kottalil [6] compared through-arch bridges at different arch positions, revealing that proper arch placement enhances both stability and aesthetics. Răcănel et al. [7] discussed "Langer-type" bowstring arches without wind bracing, highlighting efficient load transfer and reduced horizontal thrust. Similarly, Gonçalves [8] presented a comprehensive preliminary design methodology for bowstring tied-arch decks, providing valuable guidance for conceptual design and parameter optimization. The literature reveals that while bowstring arch bridges offer efficient load-carrying behavior and aesthetic appeal, addressing dynamic forces, instability, geometric configuration, and extreme events is essential for achieving long-term performance and safety.

III. SITE SELECTION

The selection of the site between Gothuruth and Chathedom across the Periyar River was guided by technical, environmental, and socio-economic considerations. This location, situated in Kerala's Ernakulam district, addresses a pressing need for improved connectivity in a region currently reliant on indirect routes and seasonal ferries. The relatively narrow river span, stable riverbanks, and proximity to existing road networks make the site technically viable and logistically accessible for bridge construction. Geotechnical investigations confirmed favourable soil conditions, supporting the use of shallow foundations. Environmentally, the bowstring arch design was chosen to minimize disruption to the river's ecosystem by reducing the number of piers in the water. Additionally, hydrological assessments revealed manageable flood risks during monsoons. Beyond feasibility, the bridge promises substantial social and economic benefits—improving access to essential services, reducing travel time, and stimulating trade and tourism. These combined factors make the site an optimal choice for the proposed bridge. Fig. 1 shows the map of that region.

Fig. 1. Map of the location

IV. TYPES OF BRIGES

A wide variety of bridge types have been developed to suit different structural, geographical, and functional requirements. Beam bridges, the simplest form, are commonly used for short spans due to their straightforward construction and efficient load transfer directly to supports. Arch bridges, on the other hand, are ideal for medium spans, utilizing compression along a curved profile to transfer loads to the abutments. Suspension and cable-stayed bridges are typically employed for longer spans; while suspension bridges rely on main cables and vertical hangers to carry loads, cable-stayed bridges transfer loads directly to towers through inclined cables, offering enhanced rigidity. The tied-arch and bowstring variants, including vertical hanger and crosstie configurations, integrate the aesthetic and structural benefits of arches with improved tension distribution and minimal horizontal thrust—making them ideal for urban and river crossings. Truss bridges use interconnected triangular units to efficiently handle heavy loads, and movable bridges serve navigation needs in waterway-rich regions. Finally, aqueduct

Proceedings DOI: 10.21467/proceedings.7.8
ISBN: 978-81-989164-8-8
Series: AIJR Proceedings
ISSN: 2582-3922

bridges are designed specifically to transport water, showcasing both historical significance and engineering innovation. Among these, the vertical hanger and crosstie bowstring bridge emerges as an optimal choice for medium to long spans like the proposed Periyar River crossing, due to its superior load distribution, minimal foundation demand, structural stability, and aesthetic appeal. Fig 2 - Fig 5 shows the different types of bridges.

Fig. 2. Beam bridge

Fig. 3. Arch bridge

Fig. 4. Suspension bridge

Fig. 5. Truss bridge

V. Methodology

The graphical representation of methodology is given as a flowchart in Fig 6.

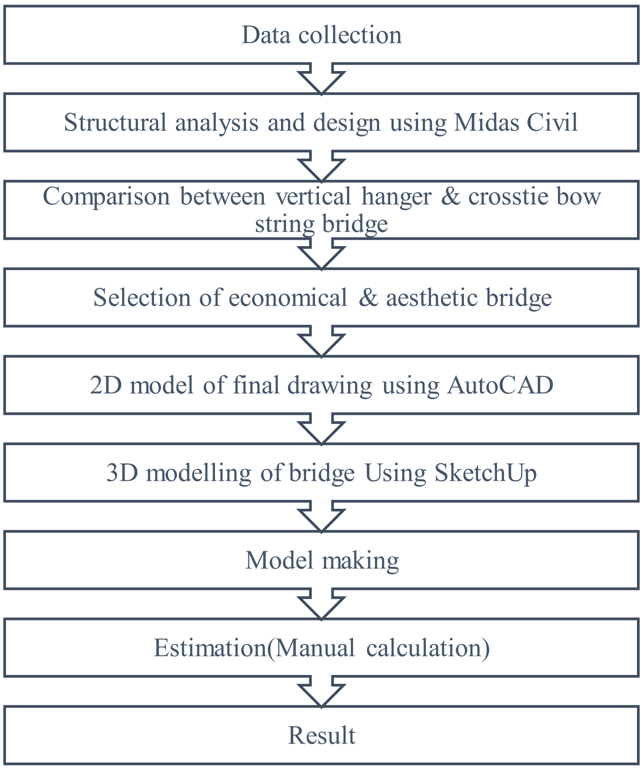

Fig. 6. Methodology

VI. Midas Civil

In this study, we explored and analyzed two distinct bowstring bridge configurations—vertical hanger and crosstie designs—using MIDAS Civil to evaluate their structural performance under realistic loading conditions. By comparing both models in terms of efficiency, material usage, and aesthetic appeal, we aimed to determine the most suitable design for spanning the Periyar River between Gothuruth and Chathedom. The vertical hanger configuration emerged as the optimal choice due to its simplicity, ease of construction, and streamlined appearance. This approach demonstrates how thoughtful application of software tools can significantly enhance bridge design decisions in practical engineering contexts.

VII. Components of a Bow String Bridge

The structural anatomy of a bowstring arch bridge is a well-balanced integration of components working together to ensure strength, stability, and functionality. At its core lies the parabolic arch, which efficiently handles compressive forces by channeling them along its curved form. The deck, supported by vertical hangers in tension, serves as the pathway for traffic and distributes live loads upward to the arch. Tie beams counteract the outward thrust of the arch, minimizing the demand on the abutments. Optional elements like piers, diagonal bracing, and

Proceedings DOI: 10.21467/proceedings.7.8
ISBN: 978-81-989164-8-8

Series: AIJR Proceedings
ISSN: 2582-3922

transverse beams enhance load distribution and structural stability under dynamic conditions such as wind and seismic activity. Altogether, these elements are anchored securely into a well-designed foundation, completing a system that is both mechanically efficient and visually striking. The Fig 7 shows the components of a vertical hanger bowstring bridge.

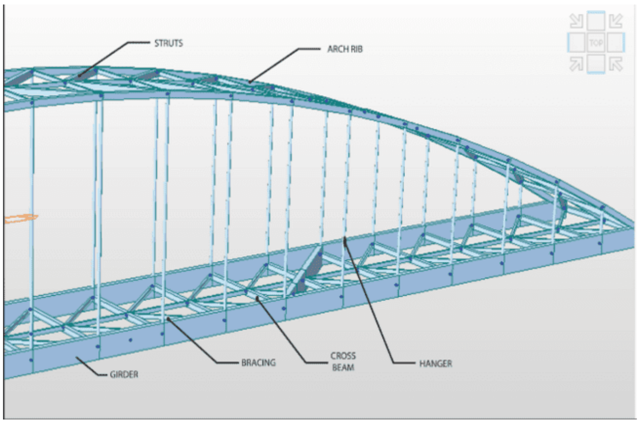

Fig. 7. Components of a vertical hanger bowstring bridge

VIII. MATERIAL USED

Material selection plays a vital role in achieving a balance between structural integrity, durability, and sustainability in the design of the bowstring bridge. High-strength structural steel (grade Fe 570) is employed for the arch, girders, bracings, and connections due to its excellent strength-to-weight ratio, ductility, and corrosion resistance when properly coated. The vertical hangers utilize Macalloy bars, prized for their exceptional tensile strength and fatigue resistance, ensuring reliable load transfer from the deck to the arch. Reinforced concrete, specifically M40 grade, is chosen for the bridge deck pavements for its high compressive strength and durability under heavy traffic and environmental exposure. Additionally, elastomeric bearings and steel reinforcements provide flexibility and support to accommodate dynamic forces and temperature variations. Sustainability considerations are integrated by incorporating recycled steel and eco-friendly concrete additives such as fly ash and slag. Together, these materials form a resilient and environmentally conscious bridge structure tailored to the demands of the site.

IX. RESULT AND DISCUSSION

In this study, detailed modeling, analysis, and design of two bowstring bridge variants—vertical hanger and crosstie—were conducted using MIDAS Civil software, focusing on a proposed bridge spanning 160 meters with a total height of 22 meters at Gothuruth to Chathedom. The vertical hanger bridge, consisting of 20 hangers and constructed with Fe 570 steel, was analyzed under various load cases based on Indian standards (IRC:6-2000 and IRC:6-2014), including dead, live, wind, thermal, and moving loads. The analysis yielded shear force, bending moment, and deflection diagrams that confirm the structural stability and efficiency of the design. Similarly, the crosstie bowstring bridge, featuring 22 segments, was evaluated with comparable load conditions, highlighting the load distribution and force transfer within the triangular truss system formed by the crossties. Complementary 2D and 3D models were developed using AutoCAD and SketchUp respectively, providing clear visualizations of the structural elements and geometry. These comprehensive analyses confirm the robustness of both bridge designs while meeting the project's functional and safety requirements. Fig 8 – 19 shows the results from Midas civil, AutoCAD, Sketch up and the physical model.

Proceedings DOI: 10.21467/proceedings.7.8
ISBN: 978-81-989164-8-8

Series: AIJR Proceedings
ISSN: 2582-3922

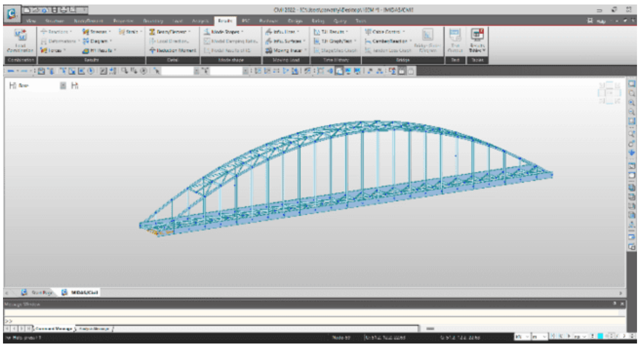

Fig. 8. Full structure of the vertical hanger bowstring bridge

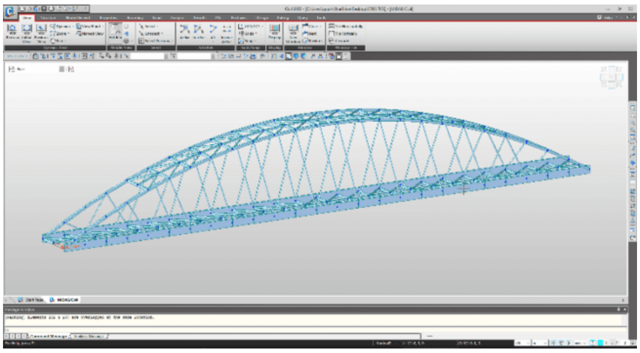

Fig. 9. Full structure of the crosstie bowstring bridge

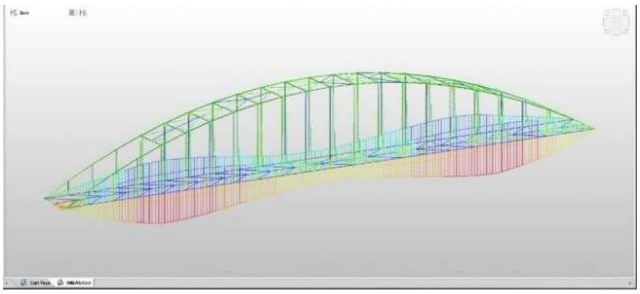

Fig. 10. Beam force diagram of vertical hanger bowstring bridge (isometric view)

Fig. 11. Deflection diagram of vertical hanger bowstring bridge (isometric view)

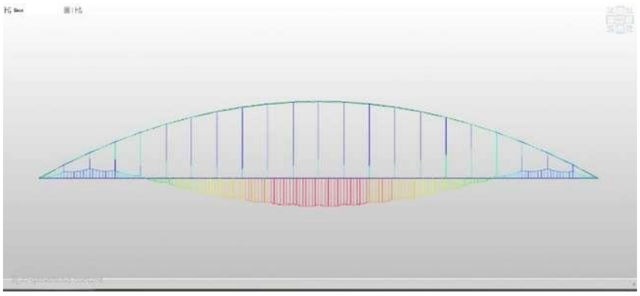

Fig. 12. Bending moment diagram of vertical hanger bowstring bridge

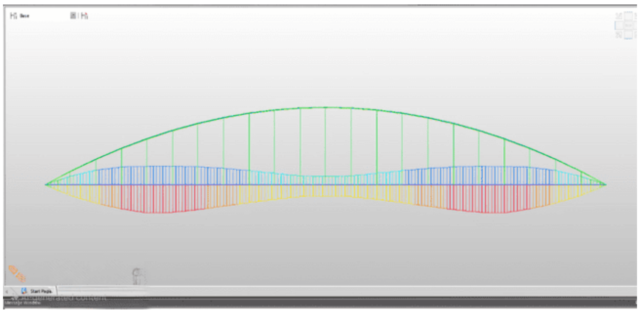

Fig. 13. Bending moment diagram of vertical hanger bowstring bridge

Fig. 14. Bending moment diagram of vertical hanger bowstring bridge

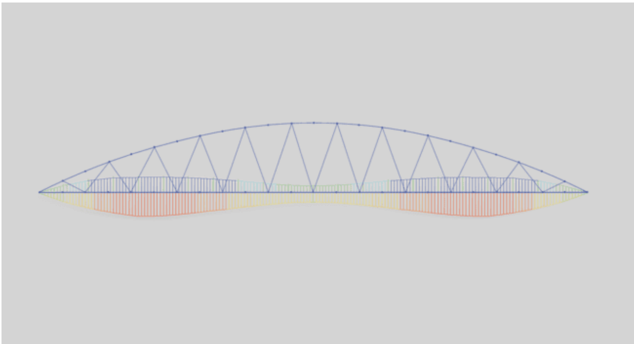

Fig. 15. Beam force diagram of crosstie bowstring bridge (isometric view)

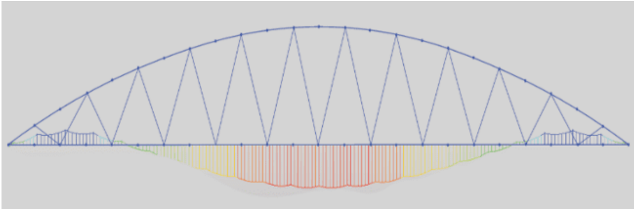

Fig. 16. Bending moment diagram of crosstie bowstring bridge

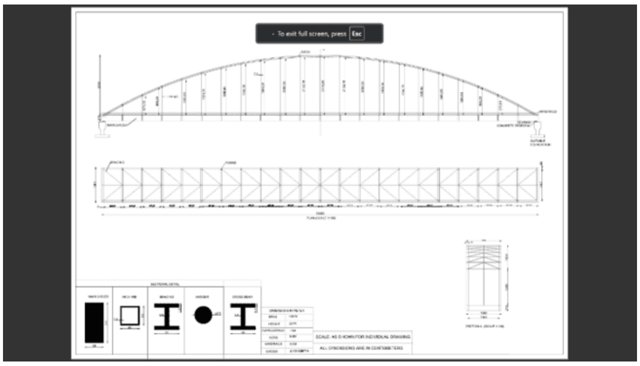

Fig. 17. 2D model of vertical hanger bowstring bridge

Fig. 18. 3D Model of vertical hanger bowstring bridge

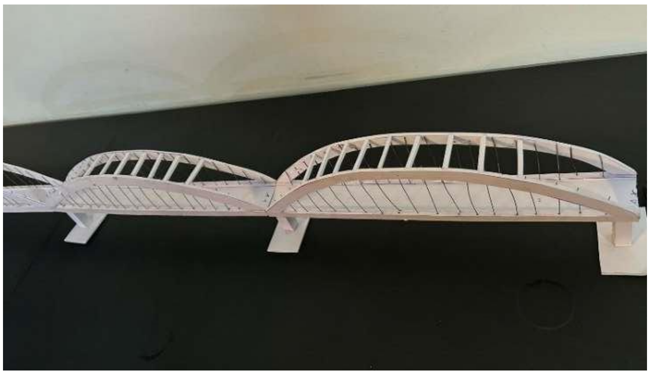

Fig. 19. Physical model of the bridge

X. COMPARSION BETWEEN VERTICAL HANGER & CROSSTIE BOWSTRING BRIDGE

In this study, the detailed modelling, analysis, and design of two bowstring bridge variants—vertical hanger and crosstie—were carried out using MIDAS Civil software for a proposed bridge spanning 160 meters with a total height of 22 meters, located between Gothuruth and Chathedom. The vertical hanger bridge, comprising 20 hangers and utilizing Fe 570 grade structural steel, was analysed under various load cases as per Indian Standards (IRC: 6-2000 and IRC: 6-2014), including dead loads, live loads, wind, thermal, and moving loads. The resulting shear force, bending moment, and deflection diagrams demonstrated the structural adequacy and efficiency of the design. Likewise, the crosstie bowstring bridge, segmented into 22 parts, was analysed under similar loading conditions, emphasizing efficient load distribution and force transfer within the triangular truss formed by the crossties. Supplementary 2D and 3D models were developed using AutoCAD and SketchUp, respectively, to visualize the structural geometry and key components. Overall, the analysis confirmed the structural reliability and suitability of both bridge configurations, satisfying both functional and safety performance criteria. Table 1 shows the Comparison between vertical hanger & crosstie bowstring bridge.

TABLE 1. Comparison between vertical hanger & crosstie bowstring bridge.

Feature	Vertical Hanger Bowstring Bridge	Crosstie Bowstring Bridge
Main Structure	Utilizes vertical hangers to support the deck.	Employs diagonal or horizontal crossties for extra stability.
Cable Configuration	Hangers are typically straight and vertical.	Crossties connect multiple points, distributing forces more evenly.
Load Distribution	Load is transferred directly through vertical hangers to the arch.	Forces are spread across a wider area with crossties, reducing strain on specific points.
Stability	Moderately stable under regular loads.	Greater lateral stability due to crossties.
Maintenance	Simpler structure may require less maintenance.	More complex design requires additional maintenance for the crossties.
Construction Complexity	Relatively easier to construct due to simpler design.	More intricate construction process because of crossties.
Visual Aesthetics	Offers a clean, minimalist look with vertical elements.	More intricate and visually complex due to the inclusion of crossties.
Common Usage	Suitable for medium to long spans in areas with lower lateral forces.	Often used in situations that demand greater lateral support, such as areas prone to strong winds or heavy traffic.

XI. ESTIMATION

In this study, the cost estimation focused solely on the steel components and deck concrete of the proposed bowstring bridge, excluding foundation works and labor charges. Using Fe 570 grade steel with a standard density of 7850 kg/m³, the material volumes were derived from the MIDAS Civil model. With the current market rate of approximately ₹69,976.44 per ton for this grade of steel, the total estimated material cost amounts to around ₹20 crores. This provides a realistic understanding of the structural material requirements and sets a foundation for further detailed budgeting. Table 2 shows the cost estimation.

TABLE 2. Estimation

Description	Units	Cost (Rs.)	Quantity	Amount (Rs.)
Main Girder	Tons	690,000/-	79.92	5,52,00,000
Arch Rib	Tons	690,000/-	21.762	1,50,15,823
Struts	Tons	690,000/-	30.19	2,11,33,000
Bracing	Tons	690,000/-	31.60	2,21,20,000
Cross Beam	Tons	690,000/-	32.40	2,26,80,000
Hanger	No	2,42,000/-	120	2,90,40,000
Concreting	Meter square	2000/-	5280	1,05,60,000

XII. CONCLUSION

This project presents the analysis, design, and comparison of two bowstring bridge configurations—vertical hanger and crosstie—for a proposed span across the Periyar River between Gothuruth and Chathedom. Based on structural behavior under various loading conditions, the vertical hanger bridge proved more viable due to its simpler design and effective load transfer. A scaled physical model aided in visualizing the bridge's real-world response. The design, focused primarily on the superstructure, was executed using MIDAS Civil, AutoCAD, SketchUp, and Lumion. Although foundation design was not covered, the study provides a solid framework for bridge selection. Future work should address the substructure for a comprehensive design.

CONFLICT OF INTEREST STATEMENT

The authors declare no conflict of interest in this study.

REFERENCES

[1] M. S. Kong, S. S. Yhim, S. H. Son, and D. Y. Kim, "Dynamic analysis of the multiple-arch bowstring bridge and conventional arch subjected to moving loads," *Steel Structures*, vol. 6, no. 3, pp. 227–236, 2006. [Online]. Available: https://doi.org/10.1007/s00158-006-0010

[2] K. Rane, S. Jaisingh, J. Visuvasam, and S. Sangtiani, "Structural evaluation of bow string and network arch bridge with different design parameters and bracings," *International Journal of Civil Engineering and Technology (IJCIET)*, vol. 9, no. 3, pp. 45–50, 2018.

[3] F. Greco, P. Lonetti, and A. Pascuzzo, "Structural integrity of tied arch bridges affected by instability phenomena," *Procedia Structural Integrity*, vol. 18, pp. 891–902, 2019. [Online]. Available: https://doi.org/10.1016/j.prostr.2019.08.133

[4] S. Akram, M. Umair, M. Alam, and S. M. Anas, "Dynamic response of bowstring-arch highway bridge subjected to above and below decks close-range large explosion," *E3S Web of Conferences*, vol. 497, p. 02023, 2024. [Online]. Available: https://doi.org/10.1051/e3sconf/202449702023

[5] P. R. Gollapudi and K. Vidhatha, "Study of effect of rise-span ratio and study of different hanger configuration in the analysis of bowstring arch bridge," *International Journal of Engineering Research*, vol. 8, no. 2, pp. 41–45, 2019.

[6] K. Koshi and L. Kottalil, "Performance comparison of through arch bridge at different arch positions," *International Journal of Scientific and Engineering Research (IJSER)*, vol. 7, no. 6, pp. 515–518, 2016.

[7] R. Răcănel, V. D. Urdăreanu, and A. Radu, "'Bowstring' arches in Langer system without wind bracing," *Romanian Journal of Transport Infrastructure*, vol. 4, no. 1, pp. 67–77, 2015. [Online]. Available: https://doi.org/10.2478/rjti-2015-0005

[8] P. P. C. A. Gonçalves, Preliminary Design of a Bowstring Tied-Arch Deck, MSc Thesis, Instituto Superior Técnico, University of Lisbon, Portugal, 2012. [Online]. Available: https://fenix.tecnico.ulisboa.pt/downloadFile/395142343222/dissertacao.pdf

[9] Indian Roads Congress, IRC:6-2014 – Standard Specifications and Code of Practice for Road Bridges, Section II – Loads and Stresses, New Delhi, India: IRC, 2014.

[10] M. Aamir, "Finite element analysis of bowstring arch bridge under blast loading," E3S Web of Conferences, vol. 497, page 02024, 2024. [Online]. Available: https://doi.org/10.1051/e3sconf/202449702024

[11] Indian Roads Congress, *IRC:6-2000 – Standard Specifications and Code of Practice for Road Bridges, Section II – Loads and Stresses*, New Delhi, India: IRC, 2000.