International Journal of Research Publication and Reviews

Journal homepage: www.ijrpr.com ISSN 2582-7421

Analysis, Design and Modelling of Cable Stayed Bridge using AR integrated BIM

Ch Leela Akash[1], D Dhtari[2], G Rahul[3], G Kaveri[4]

UG Student, Department of civil Engineering, GMR Institute of Technology, Vizianagaram District, A.P, India

A B S T R A C T :

This project focuses on the analysis, design, and 3D modelling of a cable-stayed bridge using STAAD.Pro, RCDC, and Autodesk Revit. The bridge spans 200 meters with a 25.8-meter width, a single 52-meter-high pylon, and includes four traffic lanes and pedestrian walkways. Structural analysis considered dead, live, wind, water, and seismic loads, while design was completed as per IS 456:2000. A detailed Revit model was created with realistic features and stay cables in a semi-fan arrangement. The model was cloud rendered and linked with AR using a QR code for interactive visualization. This project demonstrates how BIM and AR can enhance clarity, collaboration, and efficiency in civil infrastructure design.

Keywords: Cable-Stayed Bridge, STAAD.Pro, BIM, Augmented Reality, Revit

INTRODUCTION

The rapid advancement of construction technologies has transformed the way infrastructure projects are designed and executed. Among various bridge types, cable-stayed bridges have gained popularity for their aesthetic appeal, structural efficiency, and ability to span long distances. This project focuses on the analysis, design, and modelling of a cable-stayed bridge, incorporating modern tools like Building Information Modelling (BIM) and Augmented Reality (AR). BIM facilitates better visualization, coordination, and data management throughout the project lifecycle. AR enhances user interaction by enabling real-time visualization of 3D models in physical space. The structural analysis of the bridge was performed using STAAD.Pro, and the design was carried out in RCDC as per IS code provisions. Autodesk Revit was used to create a comprehensive 3D model of the bridge structure. Finally, AR was integrated using cloud-rendered panoramas and QR code access for enhanced presentation. This integrated approach improves both technical accuracy and stakeholder understanding, leading to more efficient infrastructure delivery.

2 LITERATURE REVIEW

So Yeong Moon et al (2015) [1]. "This paper presents an improved method for increasing maintenance efficiency of construction structures using augmented reality by a marker-less method". The study aims to establish a system using marker-less based augmented reality by presenting reality, actively utilizing BIM data created at the design stage. A SURF algorithm is used to link 3D objects and phases. The presented method can increase utilization of BIM data, offering an advanced technology stage. This could improve the efficiency of visual inspection by augmenting the model of the bridge structure.

C. Shim and Gill-tae Roh (2021) [2]. "This paper proposes data-driven modeling algorithms for cable-stayed bridges considering mechanical behavior". The digital transformation of bridge engineering utilizes distinct modeling techniques to combine domain knowledge with digital information modeling. The study proposes a data-driven modeling algorithm for cable-stayed bridges, considering the geometry change determining the mechanical behavior. Data delivery is accomplished by a combination of datasets and algorithms based on different purposes. The master information model considers alignment of the bridge and essential constraints for the main members, such as stiffening girders, pylons, and cables, between the digital models.

Omar Snchez et al (2017) [3]. "This paper studies BrIM 5D models and Lean Construction for planning work activities in reinforced concrete bridges". The study investigates the feasibility of jointly applying BrIM technology and Lean Construction philosophy, instead of individually using models for bridges. An investigative approach based on a case study is used, divided into two stages: planning 3D models and 5D Lean Construction. The integration results in early detection of problems and constraints. This detection has visualization and management advantages provided by BIM, which, along with Lean Construction principles in planning, encourage waste reduction.

Sugeng Purwanto et al (2024) [4]. "This paper reviews the integration of Building Information Modelling (BIM) in civil engineering projects". This literature review explores the integration of BIM in civil engineering projects, focusing on its benefits, challenges, and implementation. The study aims to examine the integration of BIM in civil engineering projects through a comprehensive literature review. The results of this study conclude that BIM enables more accurate and efficient design by detecting potential clashes and design errors in the early stages of the project, thus saving time and costs.

Karel Pavelka et al (2019) [5]. “This paper discusses the contribution of geomatic technologies to BIM". The paper addresses the issue of creating BIM models for older, historical objects. In this case, it is crucial to obtain a precise 3D set of complex documentation needed using various surveying techniques. The most popular technique is laser scanning and automatic photogrammetry, from which a point cloud is derived. The paper analyzes the problems associated with data conversion, especially for complex objects, shown in several case studies, including a historic medieval bridge (Charles Bridge Prague). The last part of the paper refers to the benefits of Virtual Reality in BIM.

Bida Pei et al (2023) [6]. “This paper introduces the design and key construction technology of a steel-concrete-steel sandwich composite pylon for a large span cable-stayed bridge". The paper introduces a new type of steel-concrete composite pylon that has been applied to the Nanjing Fifth Yangtze River Bridge. The application of BIM technology and the research and development of special spreaders and construction platforms ensure the precise installation of structures. Highly factory-manufactured modular assembly of the reinforced steel shell structure can effectively reduce the intensity and difficulty of on-site operations and improve the quality of the project, with low construction risks.

Muhammad Fawad et al (2024) [7]. “This paper presents the integration of a Bridge Health Monitoring System With an Augmented Reality Application Developed Using a 3D Game Engine Case Study". The research addresses the lack of interconnectivity between BIM tools, AI, IoT, and VR/AR technologies by developing an integrated framework to assess serviceability and implement a SHM for a newly constructed extradosed bridge. Using Finite Element Analysis (FEA), the study proposes a system that utilizes various IoT sensors. A BIM tool is used to develop a virtual replica, which is then used in a 3D Game Engine (GE) AR application. The paper introduces a novel inspection visualization of defects in an AR environment.

Shamima Akter Shimky et al (2024) [8]. “This paper explores the application of BIM in civil engineering". This paper explores how the use of Building Information Modeling (BIM) can be a beneficial platform for Civil engineers. The capacity of BIM for civil engineering to study many possibilities enhances results and offers data-driven confidence that projects can be completed on time and under budget. The paper discusses the difficulties encountered during the implementation of BIM technology and how they are related to the potential benefits.

Nirav V. Mody and H. D. J. Bhattiprolu [9]. “This paper discusses the design and construction of a multi-span cable-stayed bridge at Ambhora, near Nagpur, Maharashtra". The paper discusses the design and construction aspects of the bridge along with staged construction analysis. This is one of the very few cable-stayed bridges in India where all 3 methods of construction of a cable-stayed superstructure are adopted in the same bridge.

Guk-Young Jung et al (2013) [10]. “This paper focuses on the reliability analysis and utilization of BIM-based highway construction output volume". The paper developed quantity calculation algorithms for earthwork, bridge construction, tunnel retaining wall, and culvert implemented based on 3D-BIM Modeling calculation. Through estimating 3D-BIM, the proposed method is better than the existing 2D-based volume calculation method. The beginning phase involves document automation program activation in BIM.

Omkumar Pawar (2024) [11]. “This paper presents the analysis and design of a cable-stayed bridge". The paper analyses a 200m span Cable Stayed Bridge using the STAAD Pro software based on the design parameters, which includes the bending moment, shear force and displacement, Reaction Graph, Total Quantity Materail, etc.

Szabowska Paulina and Rochel Maciej (2020)[12]. “This paper describes the use of BIM technology in transport infrastructure projects". This paper describes the possibilities of using BIM (Building Information Modeling) technology based on object modeling in transport infrastructure projects, with a focus on investments such as roads and railways. The objectives of implementing this technology are presented, and its benefits for participants of the construction process are discussed.

Animikh Banerjee and Devnita Polley (2024) [13]. “This review paper provides a structural and economical analysis of cable-stayed bridges". This review paper provides a comprehensive analysis of the structural and economic aspects of cable-stayed bridges. Through the synthesis of existing literature and case studies, this paper aims to offer insights into the key factors driving the design, construction, and economic evaluation of cable-stayed bridges, thereby aiding engineers, planners, and decision-makers in making informed choices in bridge infrastructure development projects.

Tao Liu and Xiaohui Wen (2023) [14]. “This paper focuses on the integration of a Civil Engineering Intelligent Building Data System Based on BIM Technology". This paper discusses the three challenges of the traditional construction cost in the construction project. Because civil engineering is too large and covers a very broad scope, the project is easily disturbed by human factors and natural factors. It is necessary to use BIM technology to strengthen construction control and management. In actual projects, BIM technology transforms optional factors such as process and change into optimal factors, thus laying a solid theoretical and practical foundation for maximizing investment income of construction enterprises.

Wenping Liu et al (2014) [15]. “This paper aims to improve the design and construction of bridge projects using BIM: A Case Study of a Long-Span Steel-Box Arch Bridge Project". This research study aims to apply BIM (Building Information Modelling) to improve the efficiency and effectiveness of construction. Through analysis of characteristics and associated problems, a BIM-based solution for improving construction is developed, including conceptual optimization, detailed optimization sequences, scheduling, management, and process monitoring.

M. M. Bakhoum [16]. “This paper presents planning, design and construction aspects of Rod El Farag Cable-Stayed Bridge over River Nile, Cairo, Egypt". The paper presents planning, design and construction aspects of the New Rod El Farag Cable Stayed Bridge over the River Nile in Cairo, Egypt (Tahya Masr Bridge). The Bridge is the most recent Mega bridge and one of the most important bridges in Egypt.

Rong-yau Huang et al (1994) [17]. “This paper discusses the simulation of cable-stayed bridges using DISCO". The paper employs a graphically-based construction simulation system, DISCO (Dynamic Interface for Simulation of Construction Operations), for the modeling and simulation of the construction of the Pasco-Kennewick Intercity Bridge in the state of Washington. The DISCO system provides a graphical environment in which modeling and simulation of construction operations can be conducted in an interactive fashion.

3 METHODOLOGY

The project involved the analysis, design, and 3D modeling of a cable-stayed bridge using AR-integrated BIM. STAAD.Pro was used to model the structural components of the bridge, including the deck, pylons, and cables, followed by applying appropriate loads and boundary conditions to perform structural analysis. The output from STAAD.Pro was then imported into RCDC for detailed design of key elements like the deck slab, pylons, and foundations, including reinforcement detailing. Based on the design, a 3D model of the bridge was developed in Autodesk Revit with accurate dimensions and parametric components. BIM methodology was adopted to enhance coordination and data integration. The Revit model was then rendered through Autodesk’s cloud rendering platform to enable AR visualization. This allowed real-time interaction and immersive viewing of the bridge in a real-world environment using mobile or tablet devices. The combination of structural analysis, design, and AR-based BIM provided a comprehensive understanding of the bridge’s performance and constructability. This workflow also helped identify critical zones, improve design clarity, and enhance project presentation and collaboration.

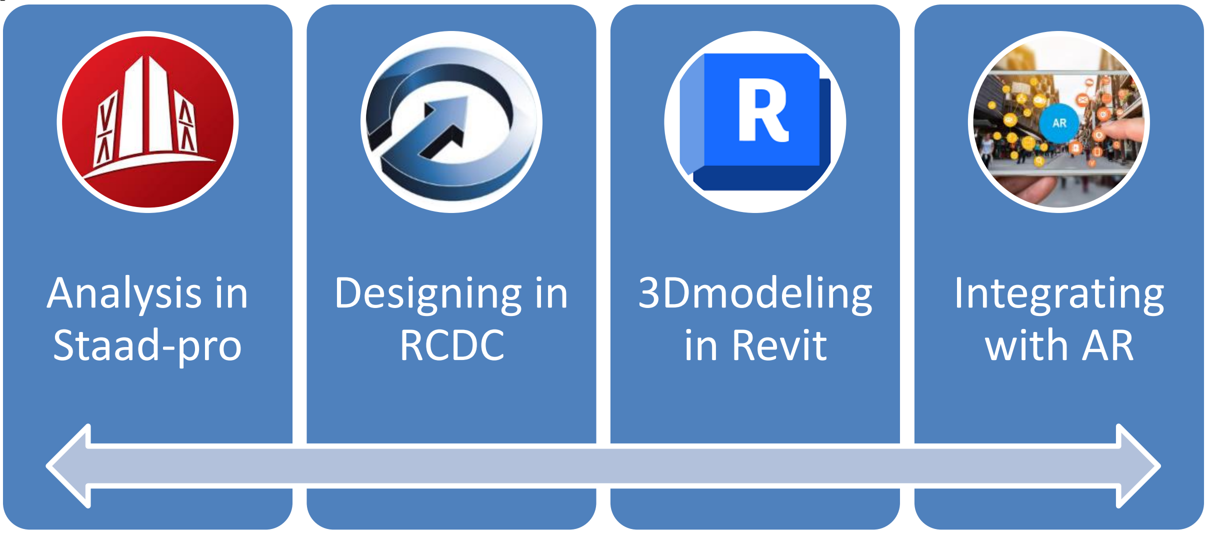


Figure 1: Proposed Methodology

3.1 Analysis in STAAD.Pro

The first phase of the project involved structural analysis using STAAD.Pro. The geometry of the cable-stayed bridge—including the deck, pylons, and cables—was modelled by defining nodes, members, and material properties. Load cases such as dead load, live load, wind load, and cable pretension were applied along with appropriate support conditions. Tension-only properties were assigned to cables to simulate real behavior. Linear static analysis was performed to study member forces, moments, and deflections. The results obtained from STAAD.Pro were verified to ensure structural stability and serviceability.

3.2 Design in RCDC

The analysis results from STAAD.Pro were exported to RCDC for detailed design. The software automatically interpreted member forces to design structural elements like the deck slab, pylons, and foundation as per IS codes. Reinforcement detailing was generated for various elements along with design reports. The design ensured structural safety, serviceability, and material optimization.

3.3 3D Modelling in Revit

Based on the design dimensions, a detailed 3D model of the cable-stayed bridge was created in Autodesk Revit. The model included all major components such as the deck, cables, pylons, and substructure. Parametric families were used for better control and future modifications. The modelling followed BIM standards to ensure accurate documentation, visualization, and data integration.

3.4 Integration with Augmented Reality (AR)

To enable immersive visualization, the Revit model was uploaded to Autodesk Cloud for rendering. The model was then accessed through Autodesk Viewer or mobile apps that support AR. This allowed the bridge to be visualized in a real-world environment using smart devices. AR integration helped stakeholders understand spatial relationships, design intent, and construction feasibility more effectively.

3.5 Bridge Design Specifications:

- **Total Span Length**: 200 meters (main span)
- **Bridge Width**: 25.8 meters
- **Pylon**:
  - **Type**: Single central pylon (mono-pylon design)
  - **Height**: 52 meters (from deck level to top)
- **Supporting Columns**: 3 piers/columns, each with a height of 10 meters (beneath the deck)
- **Traffic Lanes**: 4 lanes total
  - 2 lanes in each direction, separated by a central barrier
- **Pedestrian Walkways**:
  - Located on both sides of the deck
  - Approximately 1.5–2 meters wide each
- **Deck Arrangement**:
  - Cables anchored symmetrically from the single pylon
- **Substructure**: Central pylon with lateral supports via piers and deep foundation

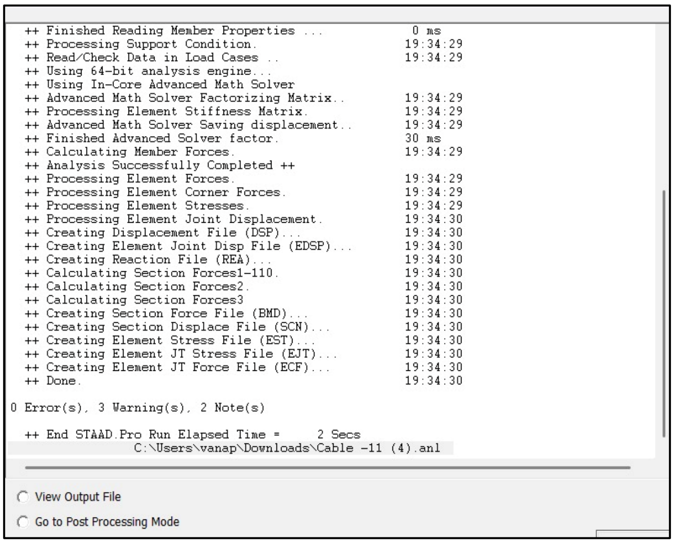
4 RESULTS AND DISCUSSIONS

As seen earlier the entire project is divided into various phases in which designing, analyzing, and implementing of AR is has taken place. The following results are obtained during the execution of the projects through all the phases.

4.1 Analysis Results

The analysis of the cable-stayed bridge was carried out using STAAD.Pro 2024, considering various structural and environmental loads including dead load, live load, wind load, water load, and seismic load. The deck, modelled with 4-meter spacing in both longitudinal and transverse directions, showed well-distributed stress patterns with deflections within serviceability limits. The single pylon experienced higher axial forces, as expected, due to its central role in cable support. The stay cables, modelled as tension-only members, showed effective load transfer from the deck to the pylon, and no cable was found to be in compression under any load case. Shear force and bending moment diagrams confirmed that maximum effects occurred near the pylon and supports, which aligned with theoretical expectations. The structural behavior was symmetrical, and the piers provided necessary vertical support without instability. Seismic load analysis based on IS 1893 showed that the structure met dynamic performance criteria, and no resonance or amplification issues were observed. Overall, the analytical model demonstrated stable performance and efficiency in load distribution across all elements.

Figure 2: Staad pro analysis with zero errors



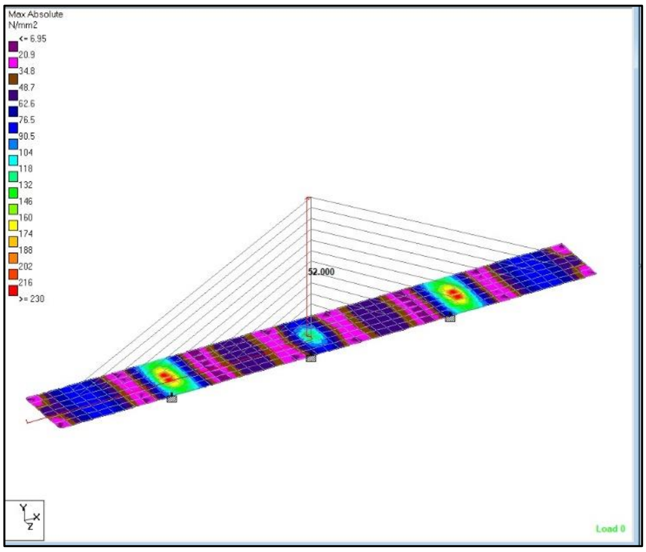


Figure 3: Stress Plate distribution diagram

4.2 Design Results in RCDC

The structural design of the deck, piers, and pylon was performed in RCDC based on STAAD.Pro analysis results and in accordance with IS 456:2000. The deck slab received adequate longitudinal and transverse reinforcement, especially near mid-spans and supports. The 10-meter-high piers were designed for combined axial and bending loads, and reinforcement was within practical limits. The central 52-meter pylon was designed to resist heavy axial and bending forces, with dense reinforcement provided at the base. All structural members passed strength and serviceability checks, and the design outputs were used for updating the Revit BIM model. The overall design was found to be safe,economical, and code-complian

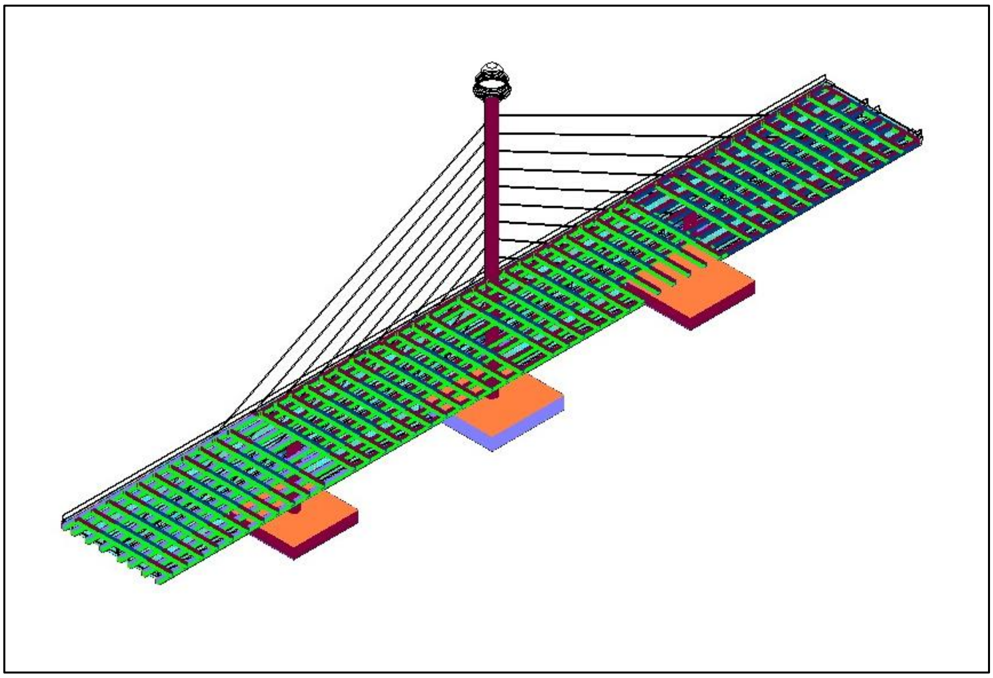


Figure 4: Reinforcement installation according to RCDC results

4.3 Revit Model Implementation Results

The 3D Revit model successfully represented all major bridge components, including the 200m deck, single 52m pylon, three piers, and stay cables in a semi-fan layout. Accurate geometry was maintained using 4-meter spacing along both X and Z axes. Traffic lanes, pedestrian walkways, parapets, and expansion joints were clearly modelled. The integration of structural data and material properties ensured that the model was both visually informative and technically accurate. Comprehensive 3D views and schedules were created for visualization and documentation. The model served as a reliable base for coordination and AR visualization.

4.4 AR Integration Results

The Revit model was integrated with Augmented Reality through cloud rendering, enabling real-time, full-scale bridge visualization. Users could interact with components like the deck, pylon, and cables in real-world environments. This enhanced design understanding, stakeholder communication, and project planning. AR integration proved to be a valuable tool for visualizing complex civil structures effectively.

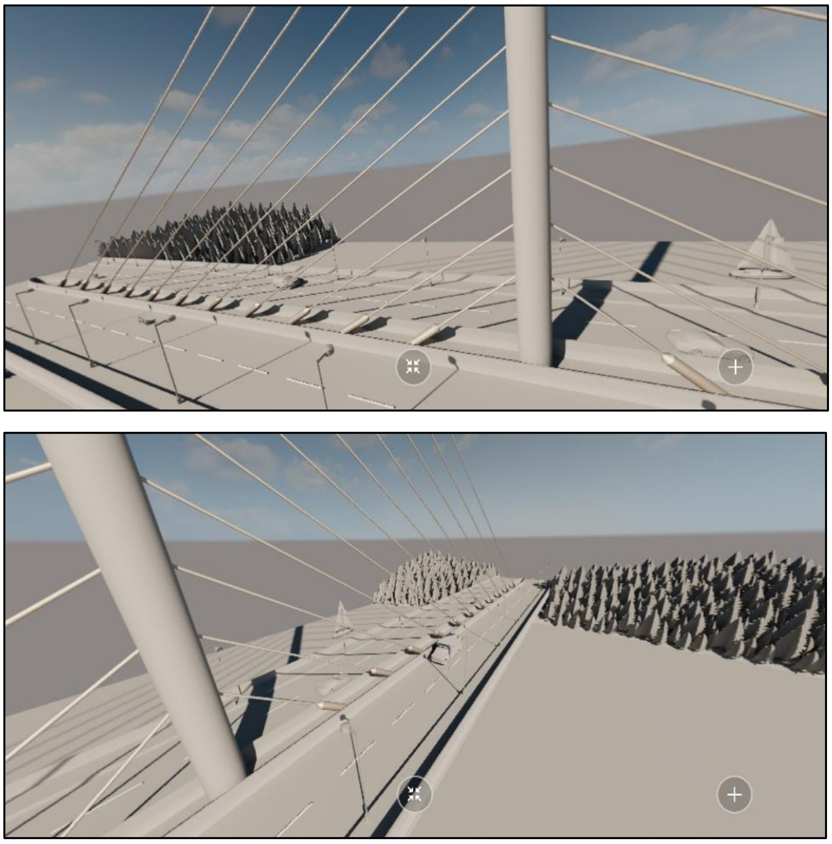


Figure 5: Augmented Reality in Revit

4.5 QR Code Generation Process

After completing the bridge model in Revit, a fixed camera view was set up to define the desired angle for AR visualization. The model was then uploaded using Revit's cloud rendering feature, and a panoramic view was generated to create an immersive experience. Once the rendering was complete, a link was sent to the registered email ID associated with the Autodesk account. By signing in through the received link, the panoramic model became accessible online. The platform then provided an option to generate a QR code linked directly to the rendered AR model. This QR code could be scanned using any smartphone to view the model in real-world surroundings, making it a convenient and effective way to share the bridge visualization.

Figure 6: QR for the Augmented Reality

CONCLUSION

- The project successfully involved the analysis, design, and modelling of a cable-stayed bridge using a combination of STAAD.Pro for structural analysis, RCDC for design detailing, and Autodesk Revit for 3D modelling, ensuring a comprehensive and integrated engineering workflow.
- Structural analysis in STAAD.Pro confirmed that the bridge components—including the deck, central pylon, and piers—were capable of withstanding various loads such as dead load, live load, wind, water, and seismic forces, with results falling within permissible limits.
- The design stage using RCDC provided accurate reinforcement details for the bridge elements. The results were validated as safe and code-compliant based on IS 456:2000 and related Indian standards, ensuring structural integrity and constructability.
- A complete 3D BIM model was developed in Revit with precise representation of bridge components such as the 200m deck, 52m high pylon, three 10m piers, pedestrian walkways, and four-lane traffic system, all spaced systematically along 4m intervals on both X and Z axes.
- The model included essential infrastructure elements like stay cables in semi-fan arrangement, parapets, and expansion joints, allowing for clear visualization of both functional and structural features of the bridge.
- Using Revit's cloud rendering feature, the model was integrated with Augmented Reality (AR), allowing for immersive and interactive visualization through mobile devices. A panoramic view was set, and a QR code was generated from the AR link for easy access.
- The QR code-based AR access made it simple for stakeholders to view the full-scale bridge model in real-world surroundings, enhancing understanding, communication, and decision-making during design review and presentation.
- Overall, the project demonstrated the efficiency and potential of combining AR with BIM in civil engineering. It bridged the gap between digital modelling and real-world perception, offering innovative approaches for future infrastructure projects.

REFERENCES

[1] "A REVIEW ON ANALYSIS AND DESIGN OF CABLE-STAYED BRIDGE," *International Journal of Advance Engineering and Research Development*, vol. 1, no. 12, Dec. 2014, doi: 10.21090/IJAERD.011218.

[2] O. Pawar, "Analysis and Design of Cable Stayed Bridge," *INTERANTIONAL JOURNAL OF SCIENTIFIC RESEARCH IN ENGINEERING AND MANAGEMENT*, vol. 08, no. 05, pp. 1–5, May 2024, doi: 10.55041/IJSREM32724.

[3] A. Banerjee and D. Polley, "Structural and Economical Analysis of Cable-Stayed Bridges," *Int J Res Appl Sci Eng Technol*, vol. 12, no. 5, pp. 2916–2931, May 2024, doi: 10.22214/IJRASET.2024.62255.

[4] S. Azan and Prof. S. Chowka, "Study on Performance of Cable Stayed Bridge with Different Geometric Conditions," *International Journal of Emerging Science and Engineering*, vol. 13, no. 1, pp. 16–22, Dec. 2024, doi: 10.35940/IJESE.K9993.13011224.

[5] X. Yu, D. Chen, and J. Yu, "Review of design and innovative construction of steel truss cable-stayed bridges in China," *Proceedings of the Institution of Civil Engineers: Civil Engineering*, vol. 177, no. 1, pp. 32–45, Jul. 2023, doi: 10.1680/JCIEN.23.00046.

[6] F. Greco, P. Lonetti, and A. Pascuzzo, "Dynamic analysis of cable-stayed bridges affected by accidental failure mechanisms under moving loads," *Math Probl Eng*, vol. 2013, 2013, doi: 10.1155/2013/302706.

[7] Y. Zeng, H. Zheng, Y. Jiang, J. Ran, and X. He, "Modal Analysis of a Steel Truss Girder Cable-Stayed Bridge with Single Tower and Single Cable Plane," *Applied Sciences (Switzerland)*, vol. 12, no. 15, Aug. 2022, doi: 10.3390/APP12157627.

[8] L. Wei, H. Cheng, and J. Li, "Modal analysis of a cable-stayed bridge," *Procedia Eng*, vol. 31, pp. 481–486, 2012, doi: 10.1016/J.PROENG.2012.01.1055.

[9] S. Hernandez, A. Baldomir, and I. Perez, "Optimization of cable cross-sectional area in long span cable stayed bridges.," *20th Analysis and Computation Specialty Conference - Proceedings of the Conference*, pp. 278–287, 2012, doi: 10.1061/9780784412374.025.

[10] I. Kobayashi, R. Miike, T. Sasaki, and H. Otsuka, "MULTILEVEL OPTIMAL DESIGN OF CABLE-STAYED BRIDGES WITH VARIOUS TYPES OF ANCHORAGES.," *Doboku Gakkai Rombun-Hokokushu/Proceedings of the Japan Society of Civil Engineers*, vol. 9, no. 4, pp. 317–325, Apr. 1988, doi: 10.2208/JSCEJ.1988.392_317.

[11] Tanvi Dilip Dongare, Prof. Jaydeep Chougale, and Dr. Ajay Radke, "Review of the Analysis and Design of Foot Over Bridge by Using Steel Truss and Girder for Seismic and Wind Conditions with Identifications of Software Applications," *International Research Journal on Advanced Engineering Hub (IRJAEH)*, vol. 2, no. 03, pp. 491–499, Mar. 2024, doi: 10.47392/IRJAEH.2024.0071.

[12] A. Camara and M. A. Astiz, "Analysis and control of cable-stayed bridges subject to seismic action," *Structural Engineering International: Journal of the International Association for Bridge and Structural Engineering (IABSE)*, vol. 24, no. 1, pp. 27–36, 2014, doi: 10.2749/101686614X13830790993762.

[13] B. Pei, A. Chong, H. Xia, and X. Kang, "Design and key construction technology of steel-concrete-steel sandwich composite pylon for a large span cable-stayed bridge," *Sci Rep*, vol. 13, no. 1, Dec. 2023, doi: 10.1038/S41598-023-33316-7.

[14] X. Xie, X. Li, and Y. Shen, "Static and dynamic characteristics of a long-span cable-stayed bridge with CFRP cables," *Materials*, vol. 7, no. 6, pp. 4854–4877, 2014, doi: 10.3390/MA7064854.

[15] J. A. Lozano-Galant and J. Turmo, "Modelling the construction of cable stayed bridges stressed with the strand by strand technique," *IABSE Symposium, Guimaraes 2019: Towards a Resilient Built Environment Risk and Asset Management - Report*, pp. 1058–1064, 2019, doi: 10.2749/GUIMARAES.2019.1058.

[16] C. S. Shim, H. R. Kang, and N. S. Dang, "Digital twin models for maintenance of cable-supported bridges," *International Conference on Smart Infrastructure and Construction 2019, ICSIC 2019: Driving Data-Informed Decision-Making*, pp. 737–742, 2019, doi: 10.1680/ICSIC.64669.737.

[17] S. Nakamura and H. Hosokawa, "Study on the fatigue design of parallel wire strands on cable-stayed bridges," *Doboku Gakkai Rombun-Hokokushu/Proceedings of the Japan Society of Civil Engineers*, no. 410 pt 1–12, pp. 157–166, 1989, doi: 10.2208/JSCEJ.1989.410_157.

[18] A. G. Yadav and P. Yadav, "Analysis of the Cable - Stayed Bridge by Varying Cable Position at Deck Level," *IOP Conf Ser Earth Environ Sci*, vol. 1326, no. 1, 2024, doi: 10.1088/1755-1315/1326/1/012036.

[19] A. Mikkonen and H. Lilja, "Loss of cable - design criteria for cable stayed bridges," *IABSE Symposium Prague, 2022: Challenges for Existing and Oncoming Structures - Report*, pp. 1763–1771, 2022, doi: 10.2749/PRAGUE.2022.1763.

[20] *J. Zhang, L. Wang, and Y. Li*, "Numerical analysis and dynamic behavior of a long-span cable-stayed bridge under multi-support excitation," *Engineering Structures*, vol. 266, p. 114476, Mar. 2022, doi: 10.1016/j.engstruct.2022.114476.