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Integrating BIM and Augmented Reality for the Analysis, Design and Visualization of a Cable Stayed Bridge

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***Abstract*— This particular project involves the analysis, design, and modeling of the 3D cable-stayed bridge using the software STAAD Pro and Autodesk Revit. The bridge has length of 200 meters along with a width of 24.8 m. It has one 50 m high pylon along with four traffic lanes and pedestrian paths. For the analysis, the loads included dead loads, live loads, wind loads, and seismic loads. The design has been carried out according to the IS 456:2000 code. A detailed Revit model has been developed with authentic details along with the fan pattern of the stay cables. The model has been cloud-rendered along with the connection with AR using QR code and web link.**

***Index Terms*— Cable stayed bridge, STAAD. Pro, Revit, Augmented Reality.**

I. INTRODUCTION

Bridges are important structures that connect places and bear various loads, including wind, traffic, and earthquakes. Cable-stayed bridges are preferred for strength, aesthetic appeal, and the ability to cover a long span with much less material. This project aims to design and analyse a cable-stayed bridge for its safety and stability using STAAD Pro under various loads. 3D Autodesk Revit detailed BIM model is then produced for accurate geometry and coordination. The bridge will, through AR, visualize interactively with improvements to understand the design better and reduce errors. The project illustrates how these digital applications can offer more efficiency and reliability in bridge design.

Bridges are integral elements of transportation infrastructure, resisting the action of traffic, wind, and seismic forces. Cable-stayed bridges have gained popularity attributed to their efficiency, elegance, and the ability to build longer spans using lower amounts of material compared to other technologies [7], [10] There has been a recognized need to analyse such structures precisely to guarantee safety and stability, particularly with regard to stay-cable behaviour under diverse load [4],[5].

The use of structural analysis programs like STAAD Pro helps assess the structural behaviour of the cable-stayed bridge accurately for various load combinations [1]. On the other hand, the application of Building Information Modelling (BIM) technology in bridge construction helps create precise 3D modelling, coordination, and lifecycle management of the structural project [2],[6],[9].

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The combination of BIM and Augmented Reality technology helps ensure the reduction of errors and better decision-making regarding the construction of the structural [1], [3].
This paper will explain the design of a cable-stayed bridge, analysis using the software STAAD Pro, BIM modelling with Autodesk Revit, along with visualization using AR, as per the guidelines of the IRC, as described in reference [7].

II. METHODOLOGY

The process involved the analysis, design, and 3D modelling of a cable-stayed bridge combined with the use of AR in BIM. STAAD.Pro analysis software was utilized for the modelling of the structural components of the bridge, which included the deck, pillars, and cables, with the subsequent application of the necessary loads and boundaries for structural analysis, while the results of the analysis in STAAD.Pro were further exported to RCDC for detailed structural design of critical components such as Deck Slab, Pillars, and Foundation, along with the provision for concrete reinforcement. On the basis of structural designs, a 3D model of the bridge was created with proper scaling and parametric components in Autodesk Revit structural analysis software. The structural analysis and design process utilized the BIM approach for coordination and data management improvements. The Revit analysis results were further visualized by rendering them using Autodesk's cloud-based rendering service for easy AR visualization capability. The detailed results of structural analysis and design combined with the use of AR based visualization in BIM resulted in a comprehensive analysis and understanding of the bridge's structural behaviour and constructability.

- Analysis and Design in STAAD.Pro
- Modelling in Revit
- Integration with AR

III. BRIDGE SPECIFICATION

This bridge has a span length of 200 m and a width of 24.8 m, carrying four lanes of road traffic. The superstructure is supported by one pylon in an H-shape, and it stands at 50 m above the deck level on top. The substructure of this cable-stayed bridge is composed of four piers and columns, 10 m high below the deck, anchored with 32 cables on each pylon in an improved fan configuration radiating symmetrically from more than one point at the top of the pylons to the deck. The H-shaped pylon with the deep foundation system gives way to a structurally stable and balanced cable-stayed bridge that can handle traffic and environmental loads.

IV. RESULT AND DISCUSSION

As witnessed above, the whole project has been divided into various phases through which the designing, analysis, and implementation of AR has occurred. The following are the results acquired during the implementation of the projects through all the phases.

A. Analysis and Design in STAAD.PRO

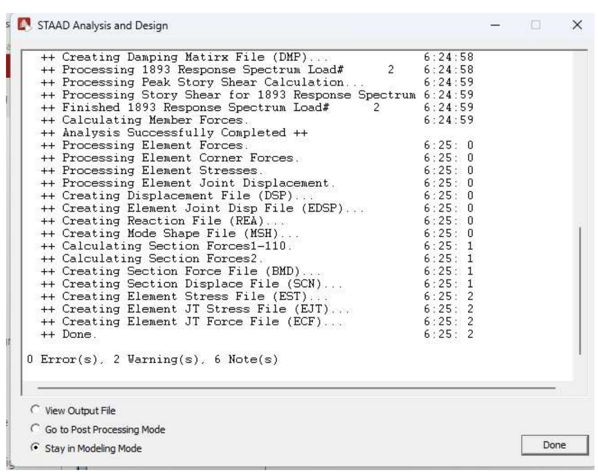

Figure 1. Analysis with zero error

The cable-stayed bridge model was analysed with software STAAD.Pro 2024, with various loading conditions such as dead load, live load, wind load, water load, and seismic load. The deck, designed with the same span between the members in the longitudinal and transverse directions, resulted in good loading distributions with adequate deflections. The single pylon showed greater axial forces, which was expected, since they are responsible for taking the total load of the cables. The tense cables resulted in good load transmission to the single pylon, with no cables in the compressed condition under any loading condition. The results for the shear force and moment curves resulted in maximum effects near the pylon or the supports, which matched expected results (fig.1). There was symmetry in the structure, with the required vertical supports without instability. The structural model for the earthquake load, with criteria based on IS1893, resulted in the structure meeting the condition for dynamic performance, with no signs of resonance or amplification. The overall structural model resulted in stable performance, showing efficiency in load distributions for the load points.
The structural design of the deck, piers, and pylon were done using the RCDC program based on the STAAD-Pro analysis output and the provisions of the IS 456:2000 code. The deck slab had sufficient longitudinal and transverse reinforcement, particularly in the mid-span and support regions. The 10-meter high piers, designed for axial and flexural loads, had reinforcement levels within reasonable limits. The 50-meter tall pylon, with heavy loads of axial and flexure had heavily reinforced base regions (Fig.2), while all members were satisfactory from the possibilities of strength and serviceability, with the design outputs being utilized for Revit BIM model updates. The whole design had demonstrated strength and economy.

TABLE I

Design Code	IS456:2000 + IS 13920:2016	
Grade of Concrete	M55	
Grade of Steel	Fe550	
Clear Cover	20.00	mm
Long Span, Ly	8.33	m
Short Span, Lx	6.20	m
Imposed Load	5.00	kN/sqm
Live Load	5.00	kN/sqm
Slab Thickness	300.00	mm
Effective Depth Along Lx, D_{effx}	275.00	mm
Effective Depth Along Ly, D_{effy}	265.00	mm
Self-Weight	7.50	kN/sqm
Total Load, TL	17.50	kN/sqm
Span	2-Way	

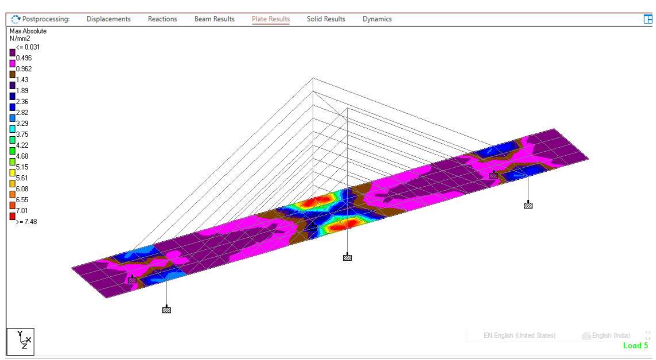

Figure 2. Stress Distribution

B. Modelling in Revit

The 3D Revit model was able to depict all major elements in the bridge, such as a 200m deck, a 50m high pylon in a single pier, three piers in total, and stay cables laid in a semi fan scheme. There was precise geometry depiction employing a 4-meter grid in both X and Z directions. Lanes, pedestrian pathways, sidewalks, and joints were explicitly modelled in the 3D Revit software (fig.3). There was cohesion of data from structure and material properties incorporated into the necessary model that helped in having an informative and precise model of all elements in the structure.

Figure 3. Revit Modelling

C. Integration with AR

The integration with the Augmented Reality was done through cloud rendering. Thus, real-time and scale-sized visualization of the bridge was achieved. Also, the components of the bridge, including the deck, pylon, and cables, were used in real-world environments. It intensified the design knowledge, communication, and planning. The integration of the Augmented Reality was effective for the visual representation of complex civil structures.

D. QR Code and Web Link Creation Procedure

After the bridge model was developed in Revit, the set angle for the AR view was accomplished using the Revit environment by establishing the view of the fixed camera. Moreover, the Revit environment facilitates the uploading of the bridge model for the creation of the cloud-rendered environment. Additionally, the panoramic view was created so as to develop an immersive environment. Subsequent to the completion of the rendering process, the direct link was sent to the registered email ID in the Autodesk account. Moreover, signing in using the link facilitated the generation of the panoramic bridge model, which was accessible using the online platform. Also, the online platform enabled the creation of the QR code and web link directly connected to the AR bridge environment, which could be scanned using any smartphone for the viewing of the bridge environment within the real-word environment, finding it quite easy and effective for the dissemination of the bridge environment as shown below.

LINK

Fig 4. QR code

V. CONCLUSION

The results from the structural analysis performed by STAAD Pro indicated that the bridge structure including deck, central pylon, and piers was capable of supporting loads like dead, live load, wind loads, water load, and seismic loads. All these results fell within the acceptable limits.

The model was developed in Revit by creating a comprehensive 3D model with a reliable representation of bridge elements including a 200m deck, a structure 50m high with a pylon, and three piers of 10m heights, a four-lane traffic system with structural elements spaced at regular intervals along the X and Z axes.

In With the cloud rendering technique of Revit, it was made compatible with AR. This enabled interactive visual explanations by means of mobile media. The view was configured to be a panorama, and a QR code was obtained through the AR link. The QR code access to AR enabled convenient access by the stakeholders to visualize the actual size model of the bridge placed in practical environments

In summary, this project has proved the effectiveness and power of AR and BIM integration in civil engineering. The project has closed the existing gap between digital understanding and actual experience, providing new solutions for future projects.

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