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Seisimic Analysis Of Cable Stayed Bridge With Different Design Of Tower Using Staad Pro

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Abstract- This research uses STAAD PRO software to conduct a structural analysis to examine the performance of cable stayed bridge with different shape of tower under different loading conditions. Results revealed that deflection is highest in an Y-shaped tower as compared to other shape, indicating that star cable arrangements will need more supports than other configurations.In the present investigation, the maximum shear force is obtained in Y-shape tower. The shear force in a cable bridge or any structure can vary depending on its design, load distribution, and applied loads. The maximum shear force in a Y-shaped tower cable bridge could be influenced by factors such as the arrangement and tension of cables, the loads the bridge is designed to carry (such as traffic or pedestrian loads), and the environmental conditions like wind or seismic forces.In the present investigation, the maximum bending momentis also obtained in Y-shape tower. The distribution of bending moments in a cable bridge or any structure depends on its design, the applied loads, and the load-bearing characteristics of the materials used. In a cable bridge with a Y-shaped tower, the distribution of bending moments will be influenced by various factors, including the arrangement of cables, the positions and orientations of the tower supports, and the type of loads the bridge is designed to carry. The bending moments are likely to be highest in regions where the structure experiences the most significant changes in curvature or where the loads are concentrated.

Keywords- Cable stayed bridge, performance, cable, tower, deflection, forces, bending moment.

I. INTRODUCTION

Cable-stayed bridges exhibit a sophisticated structural design, comprising three primary components: the deck (girder), the pylon (tower), and the cables. The synergy among these subsystems renders cable-stayed bridges exceptionally efficient for spanning extensive distances.

In the realm of structural engineering, cable-stayed bridges have demonstrated their mechanical prowess, cost-effectiveness, and aerodynamic superiority, particularly for spans ranging from 700 to 1500 meters.Nonetheless, it is imperative to acknowledge that when cable-stayed bridges are subjected to seismic forces, they confront the potential for experiencing substantial strain forces that could lead to structural impairment if not meticulously examined and accounted for. Given their pivotal role as critical infrastructure, ensuring that cable-stayed bridges exhibit an appropriate seismic response is of paramount importance.The dynamic behavior of cable-stayed bridges possesses distinctive attributes owing to the intricate interactions among the deck, cables, towers, and foundations. Furthermore, these bridges exhibit slender profiles and limited damping characteristics, further complicating their response to seismic loads. Cables are frequently utilized in structures to endure tensile forces; nonetheless, their limited damping characteristics can give rise to vibration concerns. These vibrations present notable complexities in bridge design, particularly for cable-stayed bridges exposed to diverse sources of vibration like wind, rain, traffic, and seismic activity. It is imperative to mitigate these undesirable vibrations.One strategy to tackle this challenge involves the implementation of base isolation techniques.

This approach integrates movable isolators and provides support to the deck at locations prone to vibration. Prior research endeavors that explored the seismic performance of cable-stayed bridges have been relatively scarce [1-3]. These studies have highlighted that isolation techniques can effectively diminish earthquake-induced forces on the bridge's tower but may lead to heightened deck displacement. While this can enhance travel comfort, it becomes more intricate to establish seismic joints along the longitudinal edges of the deck due to the substantial displacement response. In such instances, augmenting insulation with supplementary damping can effectively curtail excessive movement within the bridge's slabs and towers. Various forms of passive energy dissipation devices are accessible for managing the dynamic response of such structures.

The predominant focus in advancing the utilization of supplementary damping in bridges and buildings has centered on viscous fluid dampers, with an emphasis on optimizing their exceptional capacity for high-power dissipation [4]. Numerous research investigations have delved into the analytical and practical aspects of seismic isolation for buildings and bridges using viscous fluid dampers, revealing notable reductions in bearing displacement and force, resulting in the creation of more resilient structures [5-9]. In addition to this, the study in [10] explored the effectiveness of passive linear dampers and semi-active systems in mitigating the earthquake response of cable-stayed bridges. Furthermore, discussions concerning semi-active and analogous strategies for safeguarding bridges and buildings against seismic events can be found in references [11-16]. Consequently, the primary objective of this study is to perform a seismic analysis on cable-stayed bridges with various tower configurations.

II. LITERATURE REVIEW

Li et al. (2023)“examined how the spatial heterogeneity of the soil affected the seismic performance of SCCS bridges. In specifically, the Latin Hypercube Sampling approach and random field theory are utilized to construct the uncertain locations taking soil spatial variability into account. In ABAQUS, an improved 3D finite element model of a typical SCCS bridge that takes soil-structure interaction (SSI) into account is built, and stochastically simulated spatially variable seafloor seismic movements (SVSSMs) with soil uncertainties. Yi (2023) It was suggested that each cable be represented by a number of parallel elastic beam-column components with zero cross-sectional area and an equivalent number of nonlinear truss elements with a starting strain. The innovative approach helps the bridge model achieve equilibrium under dead loads and makes it possible to account for cable nonlinear vibrations including cable loosening during seismic occurrences.

Wang et al. (2023) “In order to analyze the transverse seismic behavior of inverted Y-shaped pylons in cable-stayed bridges spanning kilometers, a deformation-based pushover analysis (DPA) incorporating a novel multi-node load pattern has been proposed. The efficacy of the suggested DPA is demonstrated through a case study involving the inverted Y-shaped pylon of the Sutong Bridge. The loaded-node selection and equal displacement rule for the examined pylon are validated, affirming the suitability of the proposed multi-node load pattern for DPA.

Lin et al. (2023) “For long-span cable-stayed bridges, a life-cycle seismic performance evaluation technique based on digital twins has been developed. The three main parts of this technique are: (1) a digital twin-based structural response prediction method taking lifetime earthquake occurrence and sequence; (2) a seismic hazard analysis-based method for generating earthquake occurrence sequence; and (3) a method for quantifying service life.

Zeng et al. (2023) showed that a cable-stayed bridge performs at its best seismically when the fault-crossing angle is between 75° and 105°, since both the risk of the girder unseating and the biaxial nonlinearity of the pylon are diminished. The suggested solution effectively optimizes the damper system, balancing the case bridge's displacement and force requirement. It has been shown that the damping effects are significantly influenced by both the fault-crossing angles and earthquake characteristics.” More specifically, the fault-crossing angle is optimal for most seismic reactions when it is closer to 90° (60°-120°).

Guan (2023) “It is very difficult to design an earthquake resisting system (ERS) for long-span cable-stayed bridges because seismic isolation demands both a strong restoring force and a big deformation capacity of the girder-tower connections, especially under critical seismic situations. For the girder-tower connections, a parallel FVD and FRP cables with the requisite large restoring force and great deformation capacity are proposed as the capable and resilient lateral isolation system (CRLIS). built on the model of a useful long-span cable-stayed bridge.

Pang et al. (2022) To enhance computational efficiency and achieve a satisfactory level of accuracy, “a performance-based earthquake engineering framework was employed in conjunction with deep learning neural networks to predict fragility functions and the associated resilience index of cable-stayed bridges under seismic hazards. The suggested framework introduced improvements to the Latin hypercube sampling technique to enhance the training of the neural network. The well-trained neural network was then utilized to determine the multiple component fragilities of the cable-stayed bridge through a probabilistic simulation method.

Pang et al. (2022) suggested a probabilistic model for assessing the cable-stayed bridge's lifespan seismic resistance taking into account the impact of structural corrosion. This suggested technique took into account degrading processes such as corrosion of steel bars, weakening of concrete, and corrosion of high-strength stay cables. Then, to make seismic fragility analysis easier, a nonlinear static analysis was done to directly associate the lower seismic capabilities with the pre-defined damage states. Additionally, a cable-stayed bridge's serviceability reliability study was put into practice to enhance the quantification of the long-term and post-earthquake functionality loss.

III.RESEARCH METHOD

Performing a structural analysis of a cable-stayed bridge using software like STAAD.Pro typically involves several steps. Here's a general outline of the process:
1. Model Creation:
a. Define the geometry of the bridge, including the tower, piers, deck, and cables.

b. Create the structural elements such as beams, columns, and cables.
c. Assign material properties (e.g., steel, concrete) to each element.
d. Define support conditions (fixed, pinned) at the piers and tower bases.
e. Apply loads to the bridge, including dead loads, live loads, wind loads, and temperature effects.
2. Analysis Setup:
a. Specify the analysis type, such as static analysis, dynamic analysis, or response spectrum analysis.
b. Define load combinations to consider different load scenarios.
c. Select appropriate analysis settings, such as convergence criteria and solution methods.
3. Analysis Execution:
a. Run the analysis in STAAD.Pro, which calculates the internal forces, displacements, and reactions for each element under the specified loads.
b. Verify that the analysis converges and produces accurate results.
4. Results Evaluation:
a. Review the analysis results, including bending moments, shear forces, axial forces, and displacements in each structural element.
b. Assess the bridge's overall behavior, such as deflections, stresses, and stability.
c. Evaluate the results against relevant design codes and standards to ensure compliance.
d. Identify any critical areas or components that require further investigation or design modifications.

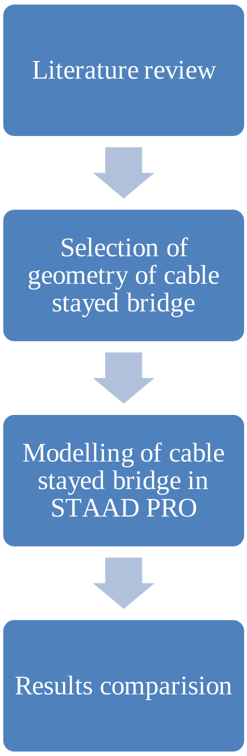

Figure 1 Research Method Adopted

Geometric Description
The span of the bridge is 200 m. The deck width is 10 m. The total height of bridge is 65 m. The pylon used here of different shape i.e. H, A and Y shape with fan arrangement of cable.

Table 1: Description of Structure

Description	Value
Total span of the bridge	200 m
Total width of the deck of the bridge	10 m
Total height of Bridge	65 m
Dia. of column	0.3 m
Beam size (1)	0.5 x 0.45 m
Beam size (2)	0.5 x 0.5 m
Deck thickness	0.3 m
Support type	Fixed support

Geometric Modelling
The structure might be generated from the input file, or the GUI can request the coordinates. The graphic below shows the GUI building process.

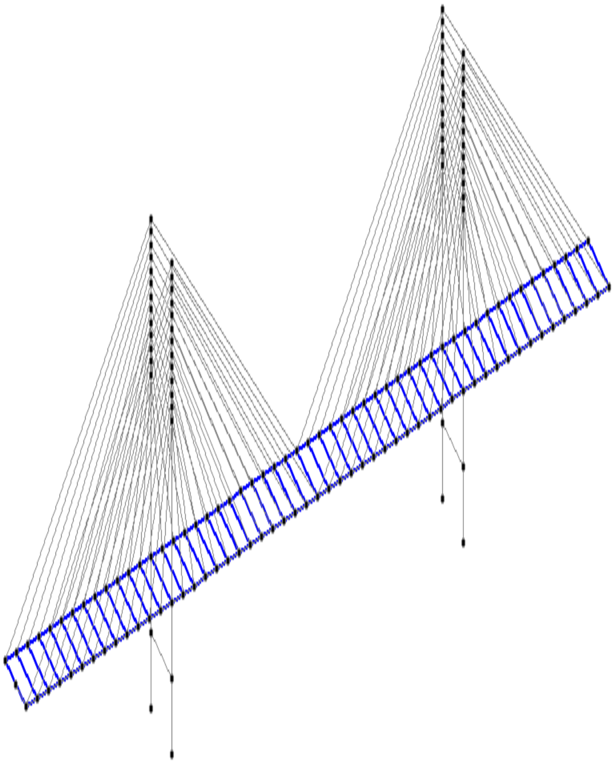

Figure 2: Fan arrangement of cable with H-shape tower

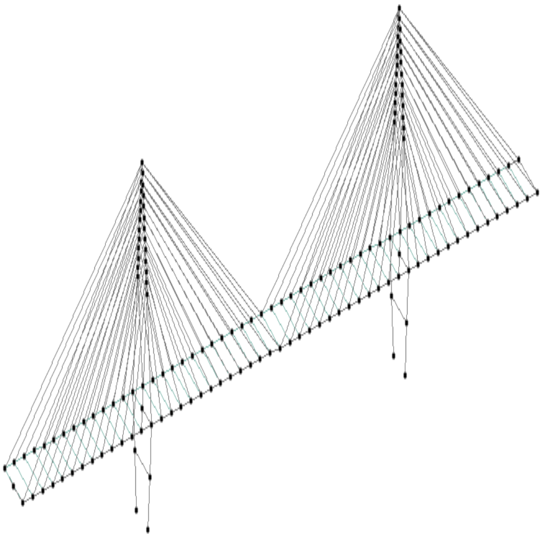

Figure 3: Fan arrangement of cable with A-shape tower

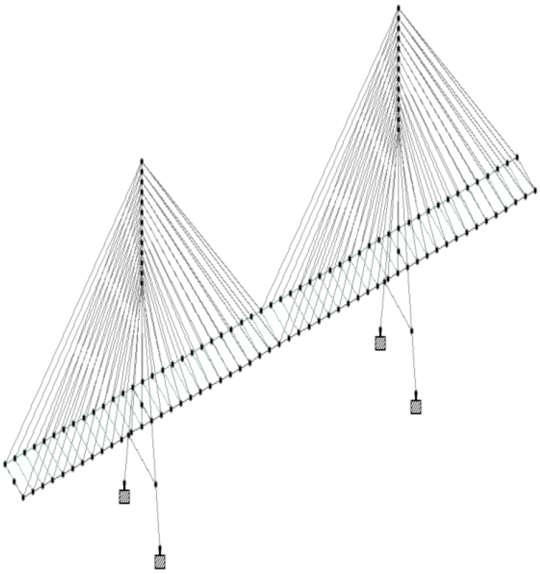

Figure 4: Fan arrangement of cable with Y-shape tower

IV. RESULTS AND DISCUSSION

1.Shear Force and Bending Moment

Figures 5 and 6 illustrate the magnitude of the maximum shear force and bending moment with respect to the tower arrangements. In this comparative analysis, it is observed that the H-tower configuration displays the highest shear force and bending moment values, while the Y-tower configuration exhibits the lowest shear force and bending moment values, contributing to a more evenly balanced structural section.

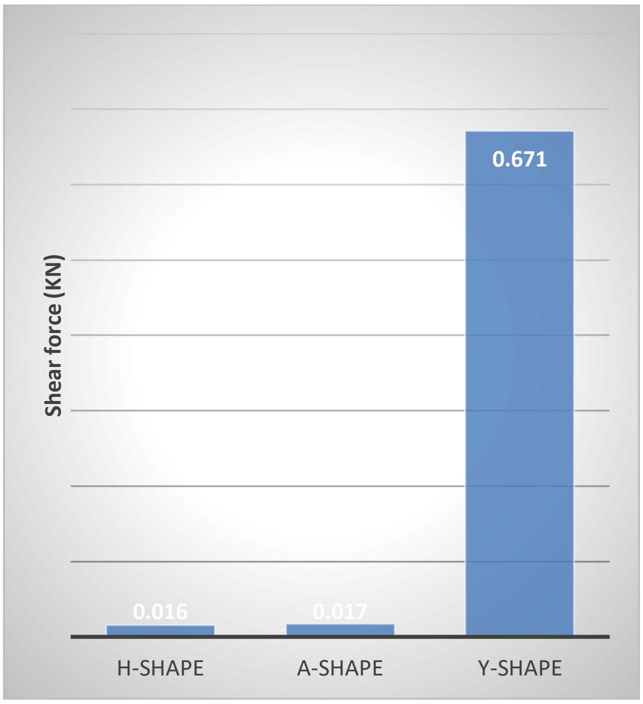

Figure 5: Variation of shear force in different tower

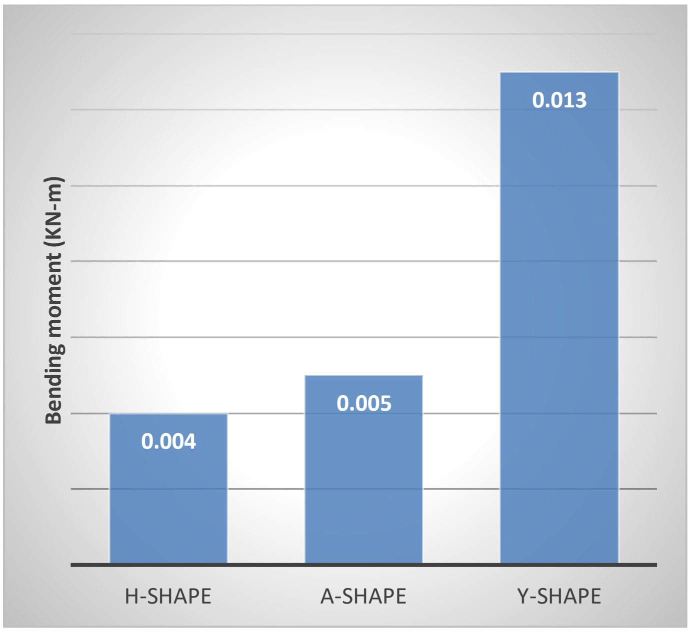

Figure 6: Variation of bending moment in different tower

2.Deflection

Figure 7 illustrates the magnitude of the maximum displacement for various tower types. It is evident that the H-shaped tower experiences the greatest deflection, while the Y-shaped tower exhibits the least deflection. This suggests that a star cable arrangement may require more supports compared to other configurations to manage deflection effectively.

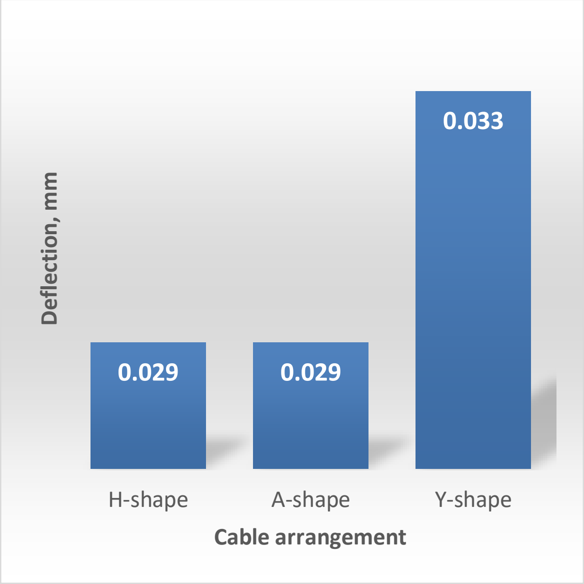

Figure 7: Deflection with different cable arrangement for H shape tower

V.CONCLUSION

This research uses STAAD PRO software to conduct a structural analysis to examine the performance of cable stayed bridge with different shape of tower under different loading conditions. The study's conclusions are as follows:

1. Deflection is highest in an Y-shaped tower as compared to other shape, indicating that star cable arrangements will need more supports than other configurations.The deflection of a tower, regardless of its shape, is primarily influenced by its geometry, materials used, and the distribution of loads along its structure. Cable arrangements, which typically involve multiple cables connected to a central point, can offer efficient load distribution and stability when appropriately designed and supported.
2. In the present investigation, the maximum shear force is obtained in Y-shape tower.The shear force in a cable bridge or any structure can vary depending on its design, load distribution, and applied loads. The maximum shear force in a Y-shaped tower cable bridge could be influenced by factors such as the arrangement and tension of cables, the loads the bridge is designed to carry (such as traffic or pedestrian loads), and the environmental conditions like wind or seismic forces.
3. In the present investigation, the maximum bending momentis also obtained in Y-shape tower.The distribution of bending moments in a cable bridge or any structure depends on its design, the applied loads, and the load-bearing characteristics of the materials used. Bending moments are moments that cause a structural member to bend or deform.

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