Analysis of a Suspension Bridge Considering Different Anchorages Using SAP2000

Sarthak Jain[1] Hitesh Kodwani[2]
[1]Research Scholar [2]Assistant Professor
[1,2]Department of Civil Engineering
[1,2]Sam Global University, Raisen, Madhya Pradesh, India

Abstract — The best option for longer spans are cable stayed bridges, and it's crucial to examine their behaviour under static and vehicular pressure. The analytical results are more satisfactory and the modelling of the cable-stayed bridge is more accurate. Although there are numerous ways to create a structural model, in the current work two distinct types of structural models—the Spine Model and the Area Object Model—are utilised to analyse a cable-stayed bridge. In order to evaluate the outcomes, static analysis and moving vehicle analysis have been carried out with the application of the IRC Class A vehicle load. To determine the optimum structure model for analysis, the analysis is carried out in SAP 2000, and the analysis results are compared with tables and graphs. This research is concerned with comparative analysis of suspension bridges considering two different forms of anchoring namely suspension bridge with tunnel anchoring and suspension bridge with gravity anchoring and the modeling and analysis is conducted using analytical application SAP 2000 considering similar loading conditions. Dead load analysis of suspension bridges and cable-stayed bridges is studied while maintaining constants in the main span, side span, pylon height, bridge deck, and material qualities. The ideal suspension bridge sag, at which the lowest magnitude of deflection is obtained, is determined by analysis. Next, the diameters of the main cables are modified, and the deflection of the bridge deck as a result is noted. Suspension bridge is then modelled with the best sag value. The optimal value is determined by the diameter at which the deck deflection is at its lowest. It is indicated how much steel was needed to achieve the desired diameter and sag. The ideal diameter of the cable used in the Cable-Stayed Bridge was determined by a similar technique. In SAP 2000, the bridges are modelled. The outcome demonstrates that, when compared to a suspension bridge of equal length, cable stayed bridges consume less steel and experience less deflection.

Keywords: Cable Stayed Bridge, Suspension Bridge, Structural Model, Spine Model, Area Object Model, IRC Class a, Finite Element Analysis, SAP 2000

I. INTRODUCTION

Cable-supported bridges are classified into cable-stayed and suspension bridges. Suspension bridges are one of the main types of long-span bridges and possess significant benefits in terms of material properties and height-span ratio of the stiffening girders. The main cables of a suspension bridge are held in place by the anchorages, which are also made up of main beams, tower piers, cables, and anchorages. Based on the main cable anchoring method, suspension bridges are classified into self-anchored or earth-anchored.

When a bridge is earth-anchored, the main cable is directly joined to the bridge via anchorages at the starting and end locations as opposed to a self-anchored bridge, where the main cable is directly tied to the stiffening girder.

II. SUSPENSION BRIDGE

A suspension bridge is referred to a type bridge supported by cables. This type of bridge has been with mankind since ancient times. Large and majestic suspension bridges of today are only conceivable because to the advancement of structural analysis techniques, building materials, construction techniques, and computer technology. One of the most exquisite peculiar bridges is a suspension bridge, which is also one of the bridge designs that many structural engineers aspire to create.

III. OBJECTIVES

1) To determine the pull out behaviour of the tunnel type anchorage and gravity type based on rock joint.
2) To investigation the load bearing capacity of the anchorage bridge with two different condition.
3) To determine finite element analysis of anchorage based bridge using analysis tool SAP2000.
4) To determine the most suitable type of anchorage in comparison.

IV. LITERATURE REVIEW

Xiangong Zhou et.al (2022) On the basis of real-world engineering scenarios, a detailed explanation of the research and analytical methodology for the structural fragility of a three-tower self-anchored suspension bridge was given.

The damage exceedance likelihood of the damped connection system is lower than that of the fully floating structural system when seismic waves are acting along the bridge. At the same time, the gap between the two systems' probabilities of experiencing damage exceedance at the same damage level keeps growing.

It demonstrates how adding a damper device can greatly boost a structure's seismic performance, and it also demonstrates how a damper device's reduction effect for a high-intensity earthquake is more pronounced than that for a low-intensity earthquake. While damage to the bridge tower is unlikely, it is likely that the piers and bearings of the floating system of the three-tower self-anchored suspension bridge will sustain minor and moderate damage. This design adheres to the principle of using secondary components in seismic designs instead of the easily repaired ones.

Zhijin Shen et.al (2022) A field-scale experiment was carried out as part of a research paper's study of the Wujiagang Bridge's north side tunnel in Yichang, China. The scale model of the 1:12 tunnel anchor was created using the similarity concept. To guarantee similar geological conditions, the tunnel anchor scale model was chosen for the region close to the project site. The design load test, overload test, overload rheological test, and ultimate bearing capacity failure test were performed using a displacement metre, inclinometer hole, strain gauge, micrometres, and other thorough monitoring techniques. The stress deformation characteristics and rheological properties of the anchorage body and surrounding rock in the field-scale experiment were examined by the structural deformation observation and stress observation of the anchorage body and surrounding rock. Investigations were conducted into the solid tunnel anchor's overload capacity, deformation failure mechanism, deformation failure process, and probable failure mode.

Nana Li et.al (2020) In the research paper, finite difference numerical software was used to examine the mechanical characteristics of the surrounding rock during the construction process in order to investigate the interaction between the left and right tunnels of the suspension bridge tunnel type anchoring. To examine the stress, displacement, and plastic zone changes of the surrounding rock of the right tunnel anchor cavern during the building of the left tunnel anchor cavern, a numerical analytical model based on FLAC3D was built. First, the left tunnel anchor cavern was excavated, then the right tunnel anchor cavern.

According to the outcomes of the numerical simulation, the construction phase of the anchor plug body and the rear anchor cavern of the left tunnel is when the right tunnel experiences the majority of its displacement. The plastic zones of the left and right tunnel anchor caverns are only joined above the midpoint of the waist wall during the excavation of the left tunnel. Therefore, it was recommended that the area above the middle of the tunnel waist wall be strengthened in advance to ensure construction safety, particularly during the excavation stage of the anchor plug body and the rear anchor cavern.

T.Subramani et.al (2019) the primary objective of the research was to investigate about suspension bridge and its components and design. Suspension bridge plan was prepared using Autocad and analysis was done using SAP software. The details of Deck slab, Cables, Supporting details of tower, Abutment design details, arrangements and sections was included. Project deals with 240m span length x 7.5m carriage width suspension bridge with basic bridge components such as Deck slab, Cable design, Suspenders and Pile foundation, abutments they are designed both Manual and Analysis using Sap. The results were found stable in the analysis.

Chang-ke Jiao et.al (2017) In a research work, a method for computing the stochastic responses of long-span flexible structures under constant and spatially variable stationary excitations was provided. This method takes into account the structure's initial equilibrium state and is carried out by integrating ABAQUS into Python to compute and process the findings of random response in batches. Taizhou Bridge is taken as an example to study the character of stochastic responses of long-span multi suspension bridges such as TSB.

The upper mid tower column's axial force, shear force in transverse direction, and bending moment RMSs are larger under uniform excitation than they are under spatially varying excitations with different apparent velocities, while the opposite is true for shear force in longitudinal direction and bending moment RMSs. The findings also show that the effects of apparent velocity on RMSs of axial force, shear force in transverse direction, and bending moment are less significant than those on RMSs of bending moment in longitudinal direction and shear force in longitudinal direction. Additionally, the findings show that perceived velocity decreases when the RMSs of the longitudinal bending moment and longitudinal shear force increase.

Luca Martinellia et.al (2016) research paper reviewed the activity of the research group active at Politecnico di Milano in the field of the dynamic behavior of Submerged Floating Tunnels (SFTs), with emphasis on the possibility to mitigate the dynamic response through structural control solutions and the modeling of seaquake effects. To evaluate the vibration mitigation under high seismic motions, an SFT model that was outfitted with adequate passive control devices was used as a case study. The tunnel is held in place at the coastlines by elastic-plastic axial springs, and it is fastened to the seafloor by bars composed of inelastic material.

Large axial forces have been detected in the anchor bars close to the tunnel ends, so that excursions in the nonlinear branch of their material behavior can appear as unavoidable. The anchoring bars largely exceed the yielding stress not only near the shore, where is can be expected due to the shorter length of the bars, but also at the quarter-span and mid-span along the tunnel. The beneficial effects coming from the nonlinear behavior of the anchoring bars result in the reduction of the bending stresses in the tunnel sections, helping protecting this critical part form loss of water tightness requirements. The simulations points out, however, that even if of limited magnitude, the local ductility demands in the anchoring bars need nevertheless to be adequately checked. The seaquake effect mainly induced a response in the vertical direction, affecting both vertical displacements and bending moments in the vertical plane. This is reflected in higher values of the bending stress at the cross-section top position.

Abhishek Pandey and Nitesh Kushwah (2020) the design and analysis for various cable arrangements with various pylon shapes using STAAD Pro were the subject of the research report. There are numerous different wire configurations, among which we selected harp, star, radial, and fan configurations. With a bridge deck height of 10 metres, the model bridge had a 200-meter span.

The findings state that "the circular or the H shape pylon can have a tiny amount of sag and moment in the cables or the deck among all the pylons (i.e. one axial layer of stay and two lateral of stays) also because bigger number with joints was not homogeneous such that the composition with pressure and anxiety carrying capacity of both the cables wasn't really efficient towards the other portions of both the cable which might lead with sec."

V. METHODOLOGY

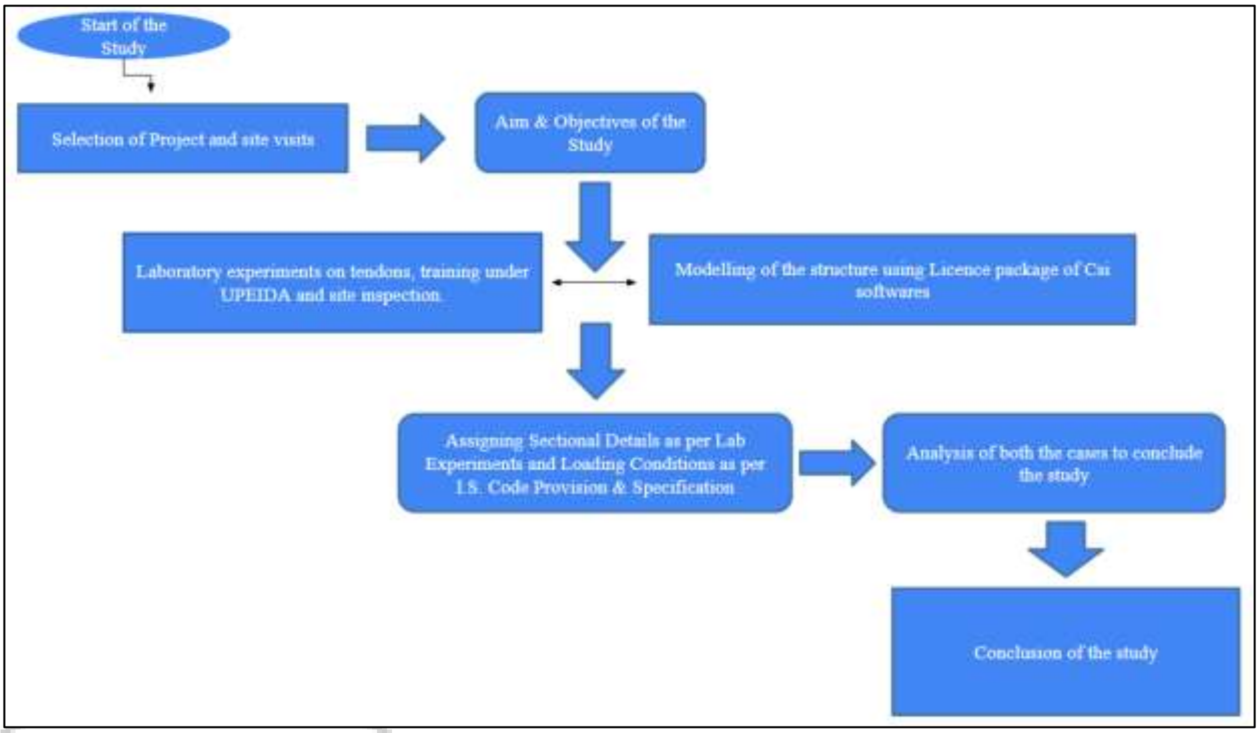

Fig. 1: Flow Chart

VI. ANALYSIS RESULTS

This research is concerned with comparative analysis of suspension bridge considering two different forms of anchoring namely suspension bridge with tunnel anchoring and suspension bridge with gravity anchoring and the modeling and analysis is conducted using analytical application SAP 2000 considering similar loading conditions.

Torsional Values in KN-m	
Bridge with Tunnel type anchorage	0.134
Bridge with Gravity type anchorage	0.063

Table 1: Torsional Values KN-m

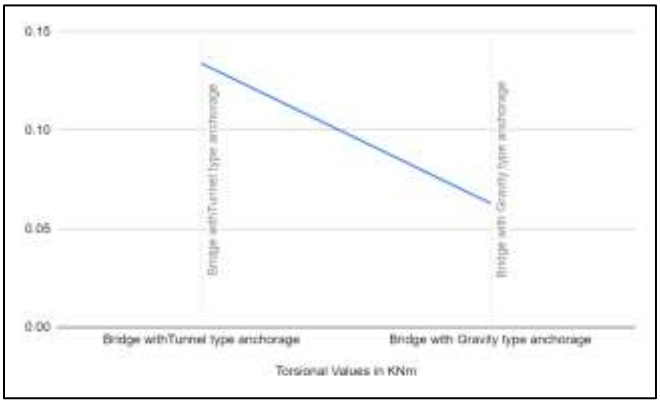

Fig. 1: Torsional Values KN-m

A. Maximum Shear Force KN

Shear force in KN	
Bridge with Tunnel type anchorage	476.098
Bridge with Gravity type anchorage	379.207

Table 2: Shear Force KN

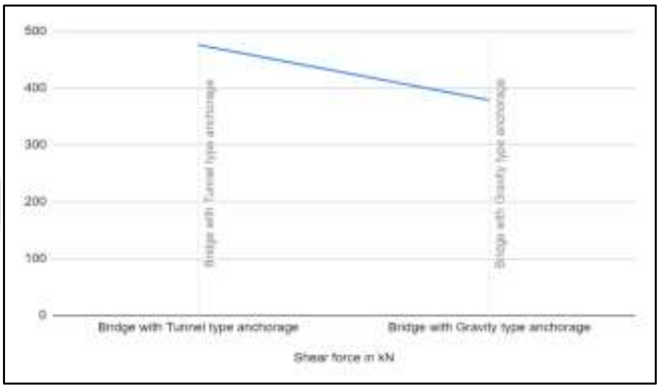

Fig. 2: Shear Force KN

B. Maximum Deflection in mm

Maximum Deflection in mm	
Bridge with Tunnel type anchorage	621.098
Bridge with Gravity type anchorage	598.992

Table 2: Maximum Deflection in mm

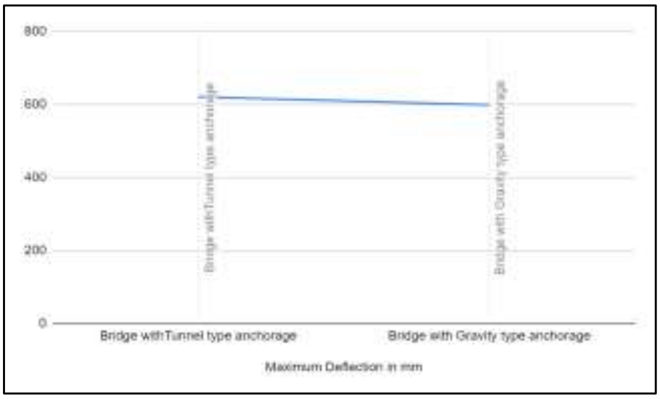

Fig. 3: Maximum Deflection in mm

C. Maximum Moment in KN-m

Maximum Moment in KN-m	
Bridge with Tunnel type anchorage	1011.88
Bridge with Gravity type anchorage	785.007

Table 3: Maximum Moment in KN-m

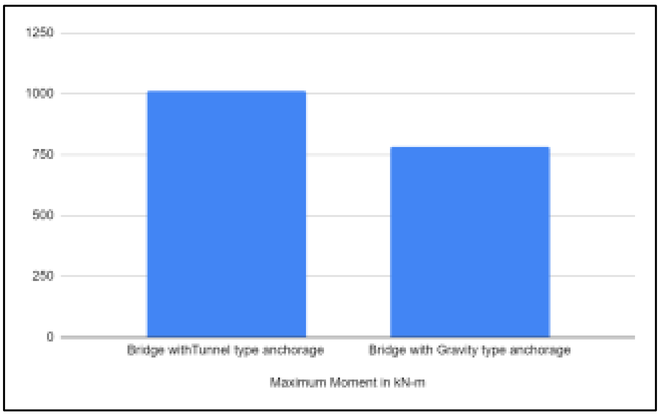

Fig. 4: Maximum Moment in KN-m

VII. CONCLUSION

Following are the ends according to the examination

1) Shear force was least found in bridges with Gravity anchorage as shear force for bridges was 379.207 KN whereas shear force for bridges with tunnel anchorage was 476.098 KN.
2) The structure was fragmental in segments to evaluate maximum displacement as a minor gap was seen in both the cases of 9% difference.
3) The state of strain in a material that has been twisted by an applied torque is known as torsion. When a structural element is subjected to a twisting force, something happens. Torsion is the state of strain that has deformed the rectangles, and it is made up entirely of pure shear. The torsion values for bridge with tunnel anchorage was 0.134 KN-m and bridge with gravity anchorage was 0.063 KN-m.
4) The maximum bending moment in a girder occurs when the shear force at that section is zero or changes sign because the bending moment is zero at the point of contra flexure. A sagging bending moment, also known as a positive bending moment, is one such bending moment. Here the bending moment was 785.007 KN-m for bridge with gravity anchorage whereas 1011.88 KN-m for bridge with tunnel anchorage.

REFERENCES:

[1] Chang-ke Jiao, Xin Dong, Ai-qun Li, Guang-dong Zhou, and Xiao-ping Wu, [Seismic Response of Long-Span Triple-Tower Suspension Bridge under Random Ground Motion], Hindawi Mathematical Problems in Engineering Volume 2017, Article ID 3457452, 16 pages.

[2] Xiangong Zhou, Lei Cao, Heng Han, Xiaobo Zheng , Hanhao Zhang and Zhiqing Zhang, [Seismic Fragility Analysis of Self-Anchored Suspension Bridge Considering Damping Effect], Hindawi Advances in Civil Engineering Volume 2022, Article ID 6980221, 12 pages.

[3] Nana Li, Yongqiang Zhou, Yanqiang Zhao and Guiju Li, [Analysis of suspension bridge tunnel-type anchorage construction on the stability of surrounding rock], E3S Web of Conferences, 2020.

[4] Zhijin Shen, Jianhong Jia, Nan Jiang, Bin Zhu and Wenchang Sun, [Field-Scale Experiment on Deformation Characteristics and Bearing Capacity of Tunnel-Type Anchorage of Suspension Bridge], Energies 2022, 15, 4772.

[5] T.Subramani, J.Karthickrajan, V.R.Perumal, A.Palani and P.Kesavan, [Design and Analysis of Suspension Bridge], International Journal of Application or Innovation in Engineering & Management (IJAIEM), Volume 8, Issue 3, March 2019, ISSN 2319 - 4847.

[6] Abhishek Pandey and Nitesh Kushwah, [Seismic Analysis and Design of Cable Stayed Bridge with Different Cable Arrangements], International Research Journal of Engineering and Technology (IRJET), Volume: 07 Issue: 12 | Dec 2020.

[7] Luca Martinellia, Marco Domaneschia and ChunxiaShib, [Submerged Floating Tunnels under Seismic Motion: Vibration Mitigation and Seaquake effects], Procedia Engineering 166 (2016) 229 – 246.