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# Analysis of Suspension Bridge with Different types of Anchoring Considering Vehicular Loading using SAP2000 : A Review

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**ABSTRACT**

Cable-stayed and suspension bridges are two types of cable-supported bridges. One of the most common styles of long-span bridges, suspension bridges offer a number of advantages in terms of the stiffening girders' height-span ratio and material qualities. 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.

In this paper presenting review of literatures related to analysis of bridge structures and loading conditions.

**Keywords :** Bridge, Concrete, Anchorage, Analysis, Force, Stress.

## I. INTRODUCTION

An engineered overpass is alluded to a sort span upheld by links. This sort of scaffold has been with humanity since old times. The present huge and sublime engineered overpasses were made conceivable through the foundation of primary investigation techniques, material turns of events, development strategies, and PC innovation advancements. Engineered overpasses are quite possibly of the most gorgeous unique extension, and are viewed as one of the kinds of scaffolds numerous primary architects dream to plan.

Ports are significant designs that communicate the flat and vertical powers of the fundamental link to the establishments. The kinds of harbors are arranged into gravity-type ports, burrow type moorings, and rock safe havens. Gravity-type mooring comprises of a strategy for opposing the heaps from the links with oneself load of the establishment and anchor outline. Numerous engineered overpasses use gravity-type ports. Burrow type dock is a strategy for opposing the heaps of the links by utilizing the shear powers of the external outline of the steel outline and the tension of the fitting body. Rock dock is a strategy for opposing the heaps of the link by utilizing the weight, grip, and frictional obstruction of rock wedges. This strategy is utilized in regions with great stone arrangements.

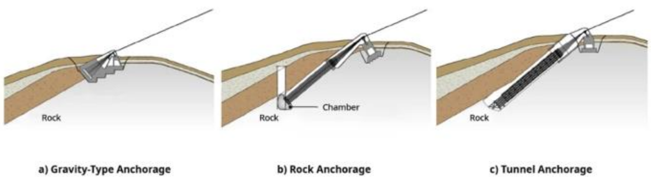


Fig 1. Anchorage Types

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## II. LITERATURE REVIEW

Xiangong Zhou et.al (2022) the research and analysis method of structural fragility of three-tower self-anchored suspension bridge was presented in detail based on practical engineering cases.
Under the action of seismic waves along the bridge, the damage exceedance probability of the damped connection system is lower than that of the fully floating structure system. At the same time, the difference in damage exceedance probability of the two systems under the same damage level continues to expand. It shows that the addition of a damper device can significantly improve the seismic performance of the structure, and the reduction effect of a damper device for a high-intensity earthquake is more obvious than that for a low-intensity earthquake. The probability of slight and moderate damage to the piers and bearings of the floating system of the threetower self-anchored suspension bridge is high, while the probability of damage to the bridge tower is relatively small. This design is in line with the design idea of taking the easily repaired components as secondary components in the seismic design.

Zhijin Shen et.al (2022) research paper conducted a field-scale experiment to study the north side tunnel of Wujiagang Bridge in Yichang, China. According to the similarity principle, the 1:12 tunnel anchor scale model was established. The tunnel anchor scale model was selected in the area adjacent to the actual project site to ensure the similarity of stratigraphic conditions. Through the use of a displacement meter, inclinometer hole, strain gauge, micrometers, and other comprehensive monitoring methods, the design load test, overload test, overload rheological test, and ultimate bearing capacity failure test were carried out. Through the structural deformation observation and stress observation of the anchorage body and surrounding rock, the stress deformation characteristics and rheological characteristics of the anchorage body and surrounding rock in the field-scale experiment were analyzed. The deformation failure mechanism, deformation failure process, potential failure mode, and overload capacity of solid tunnel anchor were investigated.
Based on the limit equilibrium analysis results of the model, the safety and rationality of the tunnel anchorage structure design of the actual suspension bridge were evaluated. According to the model experiment results, under the design load of 1P, the deformation of the rock mass at the top of the anchor tunnel is the largest, which is 0.005 mm followed by the deformation of the rock mass at the front anchor surface, and the deformation of the rock mass at the rear anchor surface is the smallest, which is 0.001 mm. According to the similarity principle, it is speculated that the maximum deformation of the front anchor surface of the solid anchor is about 1.2 mm under 1P load. Rheological test results show that the long-term rheological characteristics of tunnel anchorage are not obvious under the action of design load and step-by-step overload load, and the anchorage can be in a long-term stable state under rheological load. The scheme of tunnel anchorage on the north side of Wujiagang Yangtze River Bridge in Yichang can meet the engineering requirements.

Farhan Farid Reshi et.al (2021) research paper presented analysis and design of cable stayed and suspension bridge subjected to wind loading. The modelling and analysis of the case was done using analytical application STAAD.Pro.
Results stated that cable stayed bridge was an innovative structure and was preferred to conventional steel suspension bridges for long spans mainly due to the reduction in moments in the stiffening girders resulting in smaller section of the girders leading to economy in overall costs. This bridge type is useful for numerous traffic options, including automobiles, trucks, bicycles, and

pedestrians. In some situations, a cable-stayed bridge is suitable for light rail as well. Engineers use this option when a span must be longer than what a cantilever bridge can support because of its weight, yet it is also short enough so that suspension Cable-stayed bridges take less time to complete than other options.

Neel Shah et.al (2021) research paper analyzed the dynamic effect on different configurations of pylons of a cable-stayed bridge. A pylon is inclined at 5o , 10o , 15o , 20o , 25o and 30o with vertical and horizontal axis both and compared with vertical pylon to study the dynamic response of the bridge. The 3D bridge models was prepared on CSI BRIDGE software and the bridge is analyzed seismically by Imperial Valley 1947, Earthquake. The bridge response in terms of Pylon, Girder and Cable axial force, moment and torsion was obtained.

Results concluded that that minimum axial force we got at 10o in Cable at main span near pylon in X - Direction and Y - Direction both. Minimum axial force we got in girder at 10o at main span and side span both in X – Direction. Minimum axial force we got in pylon at 10 o in X – Direction and at 15o for Y – Direction. Minimum moment in pylon we got at 10o and minimum torsion in pylon at 5o .

Abhishek Pandey and Nitesh Kushwah (2020) research paper dealtwith the design and analysis for different cables arrangement with the different shapes of pylon using STAAD Pro. There are many types of cable arrangements among these we chose fan type, radial type, star type and harp type arrangements. The bridge's overall span was 200 m. The overall width of both the bridge's deck is 10 m.

Results stated that “The circular or the H shape pylon can have a small amount of sag and moment in the cables or the deck among all of the pylons (i.e. one axial layer of stay and two lateral of stays) also because greater number with joints was n’t homogeneous such that the composition with pressure and anxiety carrying capacity of both the cables wasn't really efficient towards the other parts of both the cable which might lead with sec, In comparison with a circular with a homogeneous member.”

Hyunsung Lim et.al (2020) in the research paper, numerical analyses was performed for a reasonable gravity-type anchorage design. The emphasis was on evaluating the effect of the passive earth pressure for gravity-type anchorages under pullout loading. Three-dimensional FE analyses was performed for different types of bedrock and embedded depths.

It was found that the displacement of the gravity-type anchorage decreased with increasing embedded depth due to the increase in the passive resistance in front of the anchorage. It is also found that the resistance due to passive earth pressure in front of the anchorage accounts for approximately 10–30% of the total resistance and thus represents a significant improvement in the prediction of the realistic resistance for gravity-type anchorages subjected to pull out loads.

Feifei Shao et.al (2020) in the research paper, three-dimensional finite element model for the Fenghuang Yellow River Bridge, with the world’s longest span of its kind under construction was established using the ANSYS finite element program, and the structural dynamic characteristics of the super long-span TSSB was investigated and compared with those of several bridges of the same type or with similar spans. In addition, the influence of the key design parameters such as the stiffening girder stiffness, tower stiffness, main cable and suspender stiffness, central buckle, and longitudinal constraint system on the dynamic characteristics of the structure was analyzed.

Analysis of the structural parameters shows that the frequencies of the longitudinal floating mode, first antisymmetric vertical bending mode, first symmetric vertical bending mode, and first torsional mode are most sensitive to the longitudinal bending stiffness of the side tower, central buckle, vertical bending stiffness of the stiffening girder, and torsional stiffness of the stiffening girder, respectively. The research findings and relevant conclusions can provide basic data for response analysis of longspan TSSBs under dynamic loads and offer an engineering reference for the design of similar bridges around the world.

Nana Li et.al (2020) in the research paper, so as to investigate the interaction between the left and right tunnels of suspension bridge tunnel type anchorage, the finite difference numerical software was used to analyze the mechanical properties of the surrounding rock during the construction process. A numerical analysis model based on FLAC3D was established to analyze the stress, displacement and plastic zone changes of the surrounding rock of right tunnel anchor cavern during the construction of left tunnel anchor cavern. The right tunnel anchor cavern was excavated firstly, and then the left tunnel anchor cavern was excavated.

The numerical simulation results stated that the main displacement of the right tunnel occurs in the construction stage of the anchor plug body and the rear anchor cavern of the left tunnel. During the excavation of the left tunnel, the plastic zones of the left and right tunnel anchor caverns are only connected above the middle of the waist wall. Therefore, it was suggested that during the construction process, especially in the excavation stage of the anchor plug body and the rear anchor cavern, the area above the middle of the tunnel waist wall should be strengthened in time to ensure the construction safety.

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) research paper presented the procedure for the computation of stochastic responses of long-span flexible structures under uniform and spatially varying stationary excitations based on PEM with the consideration of initial equilibrium state of structure, and is carried out by incorporating ABAQUS into Python language to calculate and process the results of random response in batch. Taizhou Bridge is taken as an example to study the character of stochastic responses of long-span multi suspension bridges such as TSB.

Results stated that RMSs of axial force, shear force in transverse direction, and bending moment in transverse direction of the upper mid tower column under uniform excitation are larger than those under spatially varying excitations with different apparent velocities and RMSs of shear force in longitudinal direction and bending moment in longitudinal direction are the opposite. Results also show that the smaller apparent velocity is, the larger RMSs of bending moment in longitudinal direction and shear force in longitudinal direction are, and apparent velocity has smaller effects on RMSs of axial force, shear force in transverse direction, and bending moment in transverse direction than on RMSs of bending moment in longitudinal direction and shear force in longitudinal direction.

Wen Lina et.al (2017) research paper used LSSVM and PSO analysis model and FLAC3D numerical methods to realize the intelligent displacement inversion. Through the anchor parameters inversion of the model, and establish the solid bridge anchor numerical model, analysis of anchor tunnel excavation, load and overload condition of deformation and internal force, and then analyze the stability of tunnel anchor. Under the design load, anchorage roof and side wall stress relaxation zone in the plastic zone, floor rock mass basic in flexible working condition. Increase the force of main cable and 7P, shear failure and anchor rock contact area, increase the displacement of anchorage is nonlinear.

The results stated that under the design load, the tunnel anchor maximum displacement was 5.7mm, anchorage roof and side wall stress relaxation zone was in the plastic zone, floor rock mass basicly in a flexible state. Increase the load to 7P, shear failure and anchor rock contact area, the displacement of anchorage was nonlinear. Under the overload condition, the anchor rock rupture increased significantly and produce compression, the plastic zone developed to top of deep surrounding rock, failure mode changed to compressive shear failure.

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. A SFT model, equipped with suitable passive control devices, was accounted as a case study to assess the vibration mitigation under strong seismic motions. Elastic-plastic axial springs restrain the tunnel at the shores, and bars made of inelastic material anchor the tunnel to the seabed.

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.

G. M. Savaliya et.al (2015) research paper conducted dynamic analysis of the cable-stayed suspension hybrid bridge with aspect considered as cable sag of the main cables as well as the suspension portion in cable-stayed suspension hybrid bridge. To distinguish behaviour and check the feasibility of this innovative form of hybrid bridge, 1400m central span and 312m side span cable-stayed suspension hybrid bridge is considered for analysis. The axial force in main cable was directly depending on the sag of main cable. The effects of main cable sag was investigated considering dimensionless parameters as sag to main span ratio as 1/9, 1/10 and 1/11. Results of nonlinear static analysis and modal analysis was carried out using SAP2000 v14.0.0.

Results stated that lateral bending mode time period of cable-stayed suspension hybrid bridge is found to be minimum in case of sag to main span ratio is 1/10 (Cable sag=140m) and suspension to main span ratio was 0.6. The longitudinal bending mode time period of bridge decreases with decrease in cable sag. The reason for the enhancement of bridge stiffness with a decrease in cable sag is the length of flexible main cable.

Serap Altın et.al (2012) research paper dealt with an iteration scheme for the nonlinear static analysis of suspension bridges by means of tangent stiffness matrices. The concept of tangent stiffness matrix was introduced in the frequency equation governing the free vibration of the system. At any equilibrium stage, the vibrations are assumed to take place tangent to the curve representing the force-deflection characteristics of the structure. The bridge is idealized as a three dimensional lumped mass system and subjected to three orthogonal components of earthquake ground motion producing horizontal, vertical and torsional oscillations. By this means a realistic appraisal is achieved for torsional response as well as for the other types of vibration. The modal response spectrum technique was applied to evaluate the seismic loading for the combination of these vibrations.

The concept of tangent stiffness matrix, used in conjunction with the standard modal superposition method, provides a systematic approach to the nonlinear dynamic analysis of suspension bridges. For a realistic evaluation of the overall dynamic response of a suspension bridge, a three dimensional idealization is desirable. Such an idealization permits a study of the torsional oscillations of the bridge deck. In fact, significant vibrations of this type were observed due to earthquake ground motion perpendicular to the bridge centerline.

Wen-Liang Qiu et.al (2012) research paper analyzed and investigated a series of seismic responses of a self-anchored suspension bridge, with the purpose of understanding its seismic responses in a strong earthquake zone and the effectiveness of metal dampers in reducing the seismic response. Metal dampers were installed at the joints of main girders and towers so that the energy damping effect could be investigated. The ANSYS finite element software and a space element model are used to investigate the dynamic characteristics and seismic response of the Yellow River Road Bridge. In the seismic response analysis, time-history analysis was conducted to consider the geometrical and material nonlinearity of the structure.

From the dynamic characteristics analysis, it was found that the self-anchored suspension bridge retains two specific features similar to the earth-anchored suspension bridge. One is the low mode has a longer period, the other is the concentration of vibration modes. Due to the free motion of the main girder along the longitudinal direction, the first vibration mode is longitudinal floating, which is similar to the cable-stayed bridge of the floating system. It is beneficial to the structural seismic response, but leads to large longitudinal displacement thus resulting in a seismic disaster of dropping girder or damaging expansion joints of the bridge.

## III. CONCLUSION

In past researches author illustrated the analysis of different types of bridges and their comparison but none of them explained the impact of anchoring over the stability of structure.

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