Review on Planning, Analysis and Design of Suspension Cable Bridge

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Abstract:
The requirement of long span bridge is increase with development of infrastructure facility in every nation. Long span bridge could be achieved with use of high strength materials and innovative techniques for analysis of bridge. Generally, cable supported bridges comprise both suspension and cable-stayed bridge. Cable supported bridges are very flexible in behavior. These flexible systems are susceptible to the dynamic effects of wind and earthquake loads. The cable-stayed bridge could provide more rigidity due to presence of tensed cable stays as a force resistance element. The suspension bridge could assigned more span in the field of bridge. So, combination of above two structural system the innovative form of cable-stayed suspension hybrid bridge could be the better option to provide more span. Here, attempt is made to analyze long span cable-stayed suspension hybrid bridge.

Introduction:
A suspension connect is a sort of extension in which the deck (the heap bearing part) is hung underneath suspension links on vertical suspenders. The main present day cases of this kind of scaffold were worked in the mid nineteenth century. Basic suspension spans, which need vertical suspenders, have a long history in numerous hilly parts of the world. This kind of scaffold has links suspended between towers, in addition to vertical suspender links that convey the heaviness of the deck beneath, whereupon movement crosses. This plan enables the deck to be level or to circular segment upward for extra leeway. Like other suspension connect types, this compose regularly is built without falsework. The suspension links must be moored at each finish of the extension, since any heap connected to the scaffold is changed into a strain in these fundamental links. The primary links proceed past the columns to deck-level backings, and further keep on connections with stays in the ground. Vertical suspender links or poles, called holders, uphold the roadway. In a
few conditions, the towers may sit on a feign or ravine edge where the street may continue specifically to the fundamental traverse, generally the extension will normally have two littler ranges, running between either combine of columns and the interstate, which might be upheld by suspender links or may utilize a truss scaffold to make this association. In the last case there will be next to no bend in the detachable fundamental links.

**Suspension Cable Bridge:**

Ahmad Namini, (1992) approached to computational flutter analysis is presented, which permits the determination of the critical wind velocity that initiates damping- and stiffness- driven flutter of cable- suspended bridges. The pK- F technique has demonstrated dependable in its approach and effective in its utilization. The over-generalization of the technique allows more vacillate situations to be analysed, including development stages and diverse shudder subsidiaries for various segments of the extension structure [1]. Tatjana Grigorjeva, (2010) has showed that increased deformability can be considered as the basic disadvantage of suspension bridges. One of the ways to increase the rigidity of a suspension bridge is to transfer a part of stiffening girder rigidity to a suspension main cable. To give the suspension bridge more stable appearance, the authors propose to use the cables of varying bending stiffness. The main cables can be made of standard section shapes or have a composite section. The object of this work was to study a method for analysing and determining the internal forces in the main cables and stiffening girder under static loading to provide recommendations for designing suspension bridges with stiffened cables [2].

R. Delgado, (2001) In this paper describes the dynamic tests performed on a large cable-stayed bridge, Vasco da Gama Bridge, on the basis of a nonconventional testing system, comprehending several independent accelerographs conveniently synchronized by a laptop, as well as a laser interferometry system for noncontact dynamic measurements in stay cables. This system showed to be rather portable, efficient, and accurate, leading to the creation of a very large high quality database concerning the dynamic behaviour of the bridge. Subsequent processing of the data permitted accurate identification of all the significant modal parameters of interest from the aerodynamic and seismic point of view and presented a very good correlation with the corresponding values provided by the 3D numerical finite-element model previously developed at the design stage [3]. Allan Larsen, (1998) has explained that Cross-section shape is an important parameter for the wind response and aero
elastic stability of long span suspension and cable-stayed bridges. Numerical simulation methods have now been developed to a stage where assessment of the effect of practical cross-section shapes on bridge response is possible. The present paper reviews selected numerical simulations carried out for a long-span suspension bridge using finite difference and discrete vortex methods. Comparison of simulations to existing wind tunnel data is discussed. Further, the paper addresses the aerodynamics and structural response of four generic cross-section shapes developed from the well-known plate girder section of the first Tacoma Narrows Bridge. Finally a case study involving the wind response of a 400 m main span cable-stayed bridge is discussed [4].

Hae Sung Lee., (2001) a rigorous approach for analysing the target configurations of cable-supported structures under dead loads by the Newton–Raphson method. A linearized equilibrium equation of a cable element, which includes the nodal coordinates and the unstrained element length as unknowns, is formulated using the analytical solution of an elastic catenary cable. An incremental equilibrium equation for a single cable is formed with the proposed equilibrium matrices of cable elements. The geometry of the target configuration of a cable-supported structure under dead loads is utilized to solve the incremental equilibrium equation. Detailed procedures to analyse the target configurations of suspension bridges and cable-stayed bridges are presented. The efficiency and the accuracy of the proposed method are demonstrated through numerical examples [5]. Viktor Gribniak et al., (2011) has shown that one of the main problems related to the design of suspension bridges is stabilisation of their initial form. The tendency of suspension bridges to deform is generally determined by the kinematical displacements of the suspension cable caused by asymmetrical loads rather than by the elastic deformations. There are some suspension bridges when the so-called rigid (stiff in bending) cables instead of usual flexible cables are suggested for stabilisation of their initial form. The analysis methods of such suspension bridges with rigid cables are underdeveloped. For the analysis of classical suspension bridges analytical models can be applied. However, in case of concentrated forces, the numerical techniques are preferred. The article presents analytical expressions for the calculation of internal forces and displacements of suspension bridges with a rigid cable. The article also discusses the discrete calculation model for classical suspension bridges [6].
T.J.A. Agar, (1989) explained that suspension bridges are long, slender flexible structures which have the potential to be susceptible to a variety of types of wind-induced instabilities, the most serious of which are divergence (due to stationary wind forces) and flutter (due to aerodynamic forces). Flutter occurs at certain wind speeds where aerodynamic forces acting on the deck feed energy into an oscillating structure, so increasing the vibration amplitudes. If this situation is approached the basic safety of the bridge is threatened. This paper describes a computational method for predicting flutter speed based on a modal technique. A selection of the lowest vertical and torsional natural mode shapes is included with the aerodynamic forces in an interaction analysis, which yields an unsymmetrical matrix eigenvalue problem. Flutter instability is indicated when, at some wind speed, one of the complex eigenvalue pairs resulting from the solution of the eigenvalue problem has a zero real part and a non-zero imaginary part [7].

Takeo Moriya et al., (2004) explained about a four-span suspension bridge, which has two main 2,000 m spans is investigated with respect to the deformation characteristics. Generally, deformation behaviour of the four-span suspension bridge is mainly influenced by rigidity of the centre tower. This study is focused on properties such as bending and torsional rigidity of the girder, sag ratio, and dead load. The result of this investigation clarified that the lower rigidity under live load than the three-span bridge is caused by the smaller cable spring coefficient of the main span, which is 1/6 of the side span. Nevertheless, the tendency is stable and can be assisted by stiffened rigidity of the centre tower. Live load deflection of the girder can be reduced to less than 1/200 of the main span length, which is useful and economical, by stiffening the bending coefficient of the centre tower. Moreover, relatively lower rigidity of the centre tower is sufficient for the 2,000 m span suspension bridge than for the 1,000 m span case, keeping the same deflection ratio. Three-dimensional sag geometry of the main cable is effective in limiting the torsional deformation, which is an especially important issue for the four-span suspension bridge caused by twist of the centre tower [8].

Panitan Lukkunaprasit et al., (2006) Nonlinear aerostatic stability analysis of long-span suspension bridges is studied by including directly the three combined effects of: (1) nonlinear three-component displacement-dependent wind loads, (2) geometric nonlinearity, and (3) material nonlinearity. The nonlinear three-component displacement-dependent wind loads are included through the static aerodynamic coefficients as a function of angle of attack. The various structural
buckling, such as flexural buckling, torsional buckling and flexural-torsional buckling, are considered using the element geometric stiffness matrix. Material nonlinearity is controlled using the concentrated plastic hinge model. The analytical modelling of wind-induced aerostatic instability is formulated using the finite-element method, taking into account the three components of displacement-dependent wind load as well as geometric and material nonlinearities. The numerical examples are performed on a three-dimensional finite-element model of the Akashi Kaikyo Bridge with a main span length of 1990 m. The results show that the three combined effects cause the aerostatic instability of the long-span suspension bridge. The results also indicate that the critical wind velocity for nonlinear aerostatic instability is significantly lower than the elastic flutter velocity [9].

Aly S. Nazmy et al., (1990) had explained the dynamic non-linear behaviour of three-dimensional long-span cable-stayed bridges under seismic loadings is studied. The cases of multiple-support as well as uniform seismic excitations of these long and flexible structures are considered. Different sources of non-linearity for such bridges are included in the analysis, as outlined in the companion paper. In this accompanying analysis a tangent stiffness iterative procedure is utilized to estimate the non-linear seismic response. Numerical examples are presented in which a comparison between a linear earthquake-response analysis (based on the utilization of the tangent stiffness matrix of the bridge at the dead-load deformed state which is obtained from the geometry of the bridge under gravity load conditions) and a non-linear earthquake response analysis using the step-by-integration procedure is made. In these examples two three-dimensional bridge models representing recent and future trends in cable-stayed bridge design are utilized [10].

Reference:

1. Finite Element- Based Flutter Analysis of Cable- Suspended Bridges, Ahmad Namini, Associate Member, ASCE; Pedro Albrecht, Member, ASCE. June 1992, Journal of Structural Engineering.
3. Dynamic Tests on Large Cable- Stayed Bridge, A. Cunha; E. Caetano; and R. Delgado, Journal of...


