Analysis of Hybrid Form of Cable Stayed and Suspension Bridge - A Review

Miss. Anjali Palheriya[1], Mr. Kuldeep Dabhekar[2]

[1]Student, [2]Assitant Professor,
Department of Civil Engineering, G.H.Raisoni College of Engineering, Nagpur

Abstract – *The demand of long span bridge is increasing with development in the infrastructure. To achieve maximum central span in bridges is a motivating rational challenge for engineers. The bridge with maximum central span can be get by using high quality materials and innovative formation of the structure of bridges. The cable-stayed bridge has better structural stiffness and suspension bridge has ability to offer longer span thus composition of above two structural systems could achieve very long span cable-stayed suspension hybrid bridge.*

***Keywords- Cable supported long span bridge; cable stayed suspension Hybrid Bridge; cable sag to main span ratio; dynamic analysis*.**

INTRODUCTION

A cable-stayed suspension hybrid bridge has become a popular type of bridges throughout the world because of its aesthetic shape, structural efficiency, and economical construction.

As the modern day demands put forward greater challenges for the construction of longer spans or taller structures, the better solution is possible by using high strength steel cable systems as cable supported bridges like suspended stayed or hybrid, roofs supported on cables, trusses, nets, antennae and cooling towers supported by cable systems.

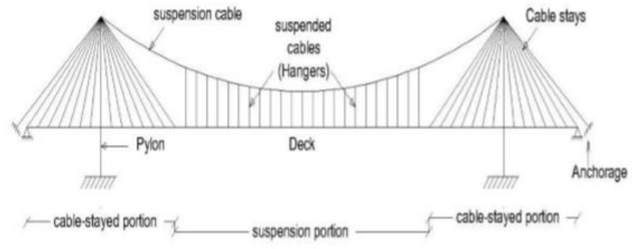

Figure 1 hybrid cable-stayed suspension bridge

1.1 Advantages of Cable-stayed suspension composite/Hybrid Bridge

Advantages of combinations of both the bridges are given below.

1. It is the innovative form of Hybrid Bridge in which the suspension part can be reduced effectively by replacement of suspender cable by cable stays, which results in reducing the axial force in the main cables.
2. As the main suspension span in the hybrid bridge is reduced the price of main cable construction and massive anchorage is also decreased.
3. On comparing with cable-stayed bridges with the same span length, the number of cable stays can be reduced. Due to this, it reduces the height of tower, length of stays and the axial forces in the deck.
4. The cantilevers during erection are also shorted and wind stability of the bridge under construction may therefore improve.

Therefore Composite cable-stayed suspension bridge becomes an effective and attractive alternative in the design of long span bridges.

II-.SUSPENSION BRIDGE

A deck of suspension bridge is connected to the vertical hangers, which are connected to main suspension cables. The main cable is continuous, over saddles at the pylons, from anchorage to anchorage.

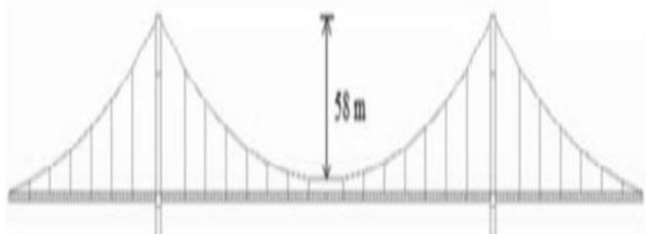

Fig. 2. Suspension bridge

[1] This paper presents the construction stage analysis of suspension bridges using time dependent material properties. For this purpose, Humber Suspension Bridge built near Kingston upon Hull, England is chosen as an example. Finite element model of the bridge is constituted using SAP2000 program considering project drawings. Geometric nonlinearities are taken into consideration in the analysis using P-Delta large displacement criterion.

The time dependent material strength of steel and concrete and geometric variations are included in the analysis. Time dependent material properties are considered as compressive strength, aging, shrinkage and creep for concrete, and relaxation for steel. The structural response of the bridge at different construction stages has been examined

[2]Located at the rocky edge of the Yerba Buena Island, the west anchorage of the San Francisco–Oakland Bay Bridge suspension span serves as the anchor for this single tower self-anchored suspension bridge. With extensive comparative studies on numerous alternatives, the new looping cable anchorage system is recommended for the final design of the west anchorage of the self-anchored suspension span. The looping cable anchorage system essentially consists of a pre stressed concrete portal frame, a looping anchorage cable, deviation saddles, a jacking saddle, independent tie-down systems, and gravity reinforced-concrete foundations. This anchorage system is chosen for its structural efficiency and dimensional compactness. This paper describes major design issues, design philosophy, concept development, and key structural elements and details of this innovative suspension cable anchorage system.

[3]The aerodynamic stability of long-span suspension bridge under erection, particularly at early erection stage, is more problematic than in the final state. It is influenced by the deck erection sequence and the nonlinear effects of wind-structure interactions. Considering the geometric nonlinearity of bridge structures and the nonlinear effects of wind-structure interactions, a method of nonlinear aerodynamic stability analysis is presented to predicate the aerodynamic stability limit (flutter speed) of long-span suspension bridges during erection. Taking the Yichang Bridge over the Yangtze River as example, evolutions of flutter speeds with the deck erected by different sequences are numerically generated. The sequences of pylons to midspan and the non-symmetrical deck erection are confirmed analytically to be aerodynamically favorable for the deck erection of long-span suspension bridges, particularly at early erection stages. The flutter speeds of long-span suspension bridges under erection are greatly decreased by the nonlinear effects of wind-structure interactions.

III- CABLE-STAYED BRIDGE

In the cable-stayed bridges, the deck is supported by the inclined stayed cables. Cable-stays support the bridge deck throughout its length, the closeness cables reduces the required depth and stiffness of the longitudinal girder to a least and hence allowing the structure of comparatively long span. In the cable-stayed bridge load of the deck is transferred to pylon through cable stays and from pylon it is transfer to foundation. The structural members like cable stays and deck are subjected to tensile forces and decks and pylons are subjected to compressive forces. In deck the effect of bending and shear is less influential. For cable-stayed bridge an iterative approach in which initially the post-tensioning cable forces in the DL configuration are determined by solving compatible conditions arising from flexibility matrix of the structure. In the cable-stayed bridge a cable-stays are making variable angles with horizontal axis, so the forces in the cable-stays are incompatible at different locations. So, the optimization procedure is utilized to minimize the cross-sections of the cable system, on the basis of the maximum effects on stress and displacement variables evaluated on the live load configurations. The requirement of incredible long span bridges is increased day by day with increase in inhabitants and their needs. To achieve a very long span bridge, use of high strength material along with novel structural system is essential. In general to achieve longer span bridges, cable-stayed and suspension systems are used, in which the cable-stayed bridge has better structural stiffness and suspension bridge has ability to offer longer span. Combination of above two structural systems could achieve a very long span cable-stayed suspension hybrid bridge.

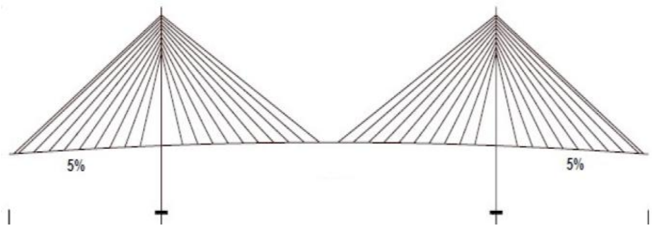

Fig. 3- Cable stayed bridge

[4] For cable-stayed bridges the cable forces are an important factor in the design process. By analyzing a simple structural system, the procedure using the analysis program MiDAS is illustrated. The generation

of the model for the finished dead stage analysis is illustrated in detail, including the boundary conditions and variations in loading. The optimization method of unknown load factor is used to determine the cable forces to achieve an ideal state. The ideal cable forces are established and a construction stage analysis is performed. The maximum cable forces are proved to be in the allowable limits. The results obtained revealed that the method presented indeed leads to optimal structural performance for the cable stayed bridge in particular, and might be a useful reference for the design of other similar bridges.

IV-CABLE-STAYED SUSPENSION HYBRID BRIDGE

The cable-stayed suspension hybrid bridge is presented as an alternative to long span cable-stayed and suspension bridges. Hybrid cable-stayed suspension bridge is combination of cable-stayed bridge and suspension bridge as shown in Fig. 1.

The analysis of cable-stayed suspension Hybrid Bridge is a new area of research. The hybrid bridge is consists of the main cables, cable-stays and hangers in a bridge, which present better performances than conventional ones based on pure suspension and cable-stayed configurations. Long span cable supported bridge highly are defined through large number of cable elements which lead to highly statically indeterminate structures. So, post tensioning forces in cables and cross sectional area of the cables can be considered as design variables, which must be determined to identify the bridge configuration under dead and live loading for economical structural steel quantity and optimum performance of structural elements. [6] Most of the existing cable supported bridges are designed by using traditional techniques, in which iterative methods based on simple design rules obtained by designer's experience and expertise were utilized .

[7] Konstantakopoulos et. al. anticipated a numerical model to investigate the dynamic behavior of a combined cable system of bridges under moving loads. The bridge's deformation under the action of moving loads was also studied. [8] Lewis presented an advanced mathematical model for the assessment of comparative material costs of the supporting elements for cable stayed and cable suspension bridges. Assessment of material supplies for each type of bridge across a range of span/dip ratios are presented in paper. [9] Lonetti et. al. proposed a methods to forecast best post-tensioning forces and dimensioning of the cable system for hybrid cable stayed suspension (HCS) bridges.

[10] Zhang et. al. has work out the limit span of self-anchored cable-stayed suspension bridge. The relations among the geometrical parameters, loads and material characteristics are also analyzed. [11] Zhang presented the mechanics performance including the static and dynamic characteristics of 1400 m main span cable-stayed suspension Hybrid Bridge. The aerostatic and aerodynamic stability etc. is investigated by 3D nonlinear analysis.[12] Zhang et. al. presented analysis of a self-anchored cable-stayed-suspension bridge with best possible cable tensions under stationary loads. [13] Zhang et.al. discussed aerodynamic stability of a 1400 m main span cable-stayed-suspension (CSS) Hybrid Bridge. Here, three-dimensional nonlinear aerodynamic stability analysis applied to study the behavior of innovative from of Hybrid Bridge. Authors suggest from the analysis carried out that the short suspension portion in main span is aerodynamically favorable. [14]Zhang studied the design parameters of Hybrid Cable-stayed Suspension Bridge with main span of 1400m by considering the geometric nonlinearity of the bridge structures. It was found from study that as some design parameters are helpful for improving the flutter stability. [15] Zhang et.al. investigated the wind stability by analyzing a hybrid bridge with main span of 1400 m. The optimal values of design parameters are determined Utilizing 3D nonlinear aerostatic and aerodynamic analysis.

CONCLUSIONS

During the last decades, many research efforts are carried out with the aim to propose proper procedure to calculate the optimum configuration of bridge. In particular zero displacement methods are based on the use of explicit constraint equations, which enforce the bridge structure under dead loading to remain practically unreformed.

The research work covers the natural vibration frequencies and principal modes of the bridge. From the literature it is found that the work related to the static and dynamic analysis of cable-stayed suspension hybrid bridge with variable length of suspension portion is inadequate. So, attention is need towards the nonlinear static and nonlinear dynamic analysis of cable-stayed suspension hybrid bridge. Hence, the current work is committed towards the nonlinear static and modal analysis of cable-stayed suspension hybrid bridge.

The dynamic analysis of the cable-stayed suspension hybrid bridge is carried out with aspect considered as cable sag of the main cables as well as the suspension portion in cable-stayed suspension hybrid bridge.

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