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Review on Comparative Study of Fan Shape and Harp Shape Cable Stayed Bridges by Using Different Parameters

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Abstract - *As demands for improved infrastructure increase around the world, civil engineers continue to be challenged to develop large bridges that must perform well even under the extreme loading. The effective means of bridging long distances in both seismic and non-seismic regions by using cable-stayed bridges. As the length of the structure increases, its developed stresses increase and hence displacement of the structure increases. The cable arrangement system is one of the load resisting systems that provide significant control on displacement and forces developed in the structure due to dead, live, wind and earthquake forces. Various studies have been carried out for determining the optimum developed stresses in the cable stayed bridges, however, the effect of parameters such as side to main span ratios, the different height of pylon and the grades of cables on optimum developed stresses has not been adequately studied. This paper aims to determine optimum weight of cables and developed stresses in cable stayed bridges with respect to side to main span ratios, the different height of pylons and the grades of the cables under the guidelines of IRC: 6-2016.*

Key Words: Cable stayed bridge structure, cable systems, Axial cable force, Deck displacement.

1.INTRODUCTION

In the past centuries, cable stayed bridges; the system was used by Egyptians for their voyaging boats. In early Chinese mankind used cable-stayed bridges to construct suspension bridges out of cables and iron chains There are many other examples of antique cable-stayed bridge systems found in the world [1, 2].

The first concrete cable stays structure was the Tempul aqueduct with the main span of 60 m in Spain in 1925. Still, the first modern cable-stayed bridge with a steel deck, designed by F. Dischinger, a German engineer, was built in Sweden in 1955, with a main span of 183 m and fan type cable configuration supported on twin column bents[1].

In India, the interest in these bridges could be developed only after the proposal of the second Hooghly Bridge, a cable-stayed type. It is a six-traffic-Lane bridge with a main span of 457.2 m and two side spans of length 182.88 m on each side [2].

In recent years, the performance of cable stayed bridges under seismic loads, wind load and traffic load excluding the case of non-uniform excitation, have been satisfactory since no serious damage has been reported. Because of their efficient, economically feasible, faster construction and aesthetically eye-catching looks have made cable stayed bridges the most widely used bridge system for medium to long-span bridges. Nowadays, almost 90 percent of long-span bridges are cable-supported bridges [3, 4, 6]. The cable stayed bridge with a length greater than 1Km is being constructed (Sutong cable stayed bridge, China) [5].

Many new techniques such as cable arrangements, type of deck, shapes of the pylon, types of the cable, base isolation, dampers, etc. are developed to control the excessive deflections and drifts in the cable stayed bridge structures [7]. However, the fan and harp cable systems are found to be more preferred in cable stayed bridge structures particularly in the wind or seismic regions

1.1 Cable Structural Systems:

Cable structural system is broadly classified into
(a) Fan cable system
(b) Harp cable system

(a) Fan cable system:
In this system, all cables are connected at the top of the pylon and Cable-stayed bridges with fan arrangement have been used, for which all stay cables converge into a single point at the top of the pylon. The fan cable system is structurally superior with a minimum moment applied to the towers [6]. structure as shown in Fig -1.

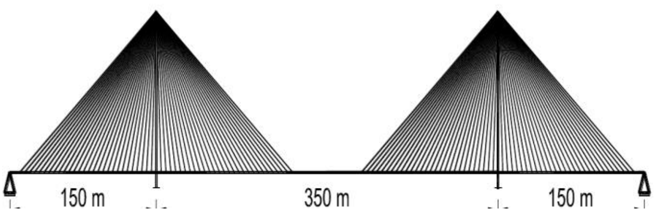

Fig 1: Fan cable system [6]

b) Harp cable system:
In the harp or parallel design, the cables are nearly parallel so that the height of their attachment to the tower is proportional to the distance from the tower to their mounting on the deck [1].

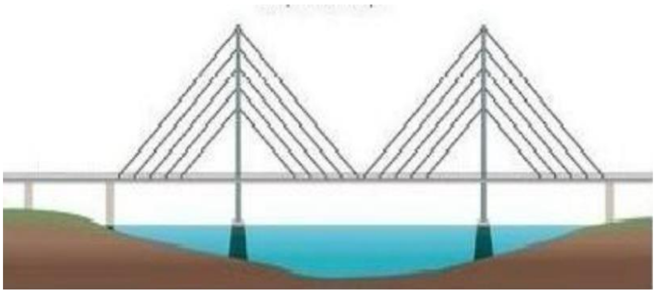

Fig -2: Harp cable system [1]

The research studies indicate that the Fan cable system is more efficient than the Harp cable system in providing strength and stiffness to resist the loads induced by traffic, wind, and earthquake in cable stayed bridge structure [9].

1.2 Optimum cable stayed bridges:

The optimum developed stresses of these cable stayed bridges depend on a side to main span ratio, the height of the pylon, grades of cables, location of the structure, type of the deck, the diameter of the cables. [2, 4, 6].

From the above study, it is found that optimum and efficient developed stresses in the fan cable arrangement of side to main span ratio of 0.45 and height of pylon L/4. [2, 11].

2. LITERATURE REVIEW

Many researchers have studied the behavior and performance of the cable stayed bridges in the long span structure, especially in the seismic active regions. The present theories published by various researchers related to the behavior of cable stayed bridge structure using different cable arrangements are presented in the following section.

Muhammad Habib (2020), analysed a Three-dimensional non-linear seismic analysis of a cable-stayed bridge using ANSYS software, the response of the cable-stayed bridge is examined by carrying out non-linear static and dynamic analyses. The transient analysis was performed for EI-Centro 1940 ground motion data of 10 seconds with a time interval of 0.0001 seconds. Modes and the natural frequency of the bridge are studied by Modal analysis based on the Block Lanczos method. The conclusion obtained from this study is the bridge has complex modes due to the coupling effects for the free vibrations and it is more flexible in the vertical direction than in transverse and longitudinal directions [3].

Mohammad Jafri and Partha P. Sarkar (2020), present the Experimental- and numerical-model-based study on Wind-induced response characteristics of a yawed and inclined cable in ABL wind. the wind-induced response of an inclined smooth cable was studied through wind tunnel measurements using a flexible cable stayed bridge model for a better understanding of the vibration characteristics of structural cables in atmospheric boundary layer wind. In this study, the four cases with different yaw and inclination angles of a cable with approximate sag ratios of 1/10 were studied to examine the wind directionality effect on its excitation modes and response amplitude. The experimental results indicate the excitation modes of a cable depend on wind speed, inclination angle, and sag ratio, and cable tension [10].

Shiravand and P. Parvanehro (2019), conducted a comparative study on Spatial variation of seismic ground motion effects on nonlinear responses of Cable-stayed bridges considering different soil types For this purpose, three cable-stayed bridges were modeled in SAP2000 software and imposed to uniform and non-uniform displacement time series with lengths of 400, 800and 1200m. Consider different types of soils for generating the sixteen different load cases. The results indicate that depending on the soil type beneath each support, the response of the bridge may vary significantly. Girder moment, cables axial force, pylons shear, and pylons drifts are amplified up to 1.8, 1.4, 1.48, and 3.1 correspondingly in the worst load case [4].

Puneet Garg and Rajesh Chaturvedi (2019), analyzed two different types of structural models viz. The spine Model and Area Object Model are used for the analysis of cable-stayed bridges in CSi Bridge software. Static analysis and moving vehicle analysis have been done in which IRC Class A vehicle load is applied and their load combination is considered. The results indicate that a structure model that gives satisfactory results [8].

Zuber Ahmed and Esar Ahmed (2017), analyzed the seismic response of cable-stayed bridges with a single pylon and two equal side spans. The models have been analyzed in CSB Sap-2000 for the dead load (static) and dynamic loads under the effect of load time histories of the Bhuj, El Centro, and Uttarkashi earthquakes. The author concluded that, that the Three-dimensional models have been used to realistically model the complex geometry and configuration of towers and also to represent the actual dynamic behavior of the bridge for seismic analysis [1].

Umang A. Koyani and Kaushik C. Koradia (2016), three-span, two planes fan and harp shape cable-stayed bridge with box girder deck is considered. The various parameters were considered for analysis of the cable-stayed bridges those upper strut heights, side to main span ratio, cable system, number of cables per plane, and diameter of cable. Under the IRC class AA moving load. The analysis is carried out with help of MIDAS Civil software. The result indicates that the increase in side to main span ratio maximum moment is decreasing up to a certain limit and then increases. With the increase in the number of cables the maximum moment in the girder decreases [6].

Shehata E. Raheem et al. (2012), study the nonlinear static behavior of cable-stayed bridges, develop a set of consistent design as well as a viability study of long-span cable-stayed bridges over the Nile River. In this work Three-span cable-stayed bridge has been analyzed by using Sap-2000, the effects of the variation of a cross-section of cables, cable layout either fan or harp pattern, pylon height to span ratio, and mechanical properties of deck and pylon on the straining action of the bridge elements. The author concludes that the fan layout cable system shows a higher normal force response compared to that of the harp system [9].

T. P. Agrawal (1997), The study was carried out for double-plane bridges with 12, 20, 28, and 36 cables per plane, with side to main span ratios of 0.35, 0.40, 0.45, and 0.50, respectively. The bridges were analyzed by the stiffness matrix method, treating the bridges as two-dimensional structures On the IBM 360 mainframe computer. The investigation shows that maximum cable rapidly with the increase in the number of cables. Considering the side to main span ratios of 0.35 and 0.40, the cable tension increases with the decrease in length of the central panel. For side to main span ratios of 0.45 and 0.50, for a smaller number of cables, it increases with the decrease in length of the central panel, but for a larger number of cables, the trend reverses. For bridges with 16 cables, the cable tension becomes equal in both cases. However, in general, the difference in cable tension in the preceding two cases of panel lengths is very small [2].

3. CONCLUSIONS

From the literature review, following conclusions can be drawn:

i. The behavior of the cable stayed bridge depends upon the cable arrangement type, type of cable, nature of structure and service requirement, parameters such as side to main span ratio, the height of pylon, and the material used for cable stayed bridge components.
ii. The fan cable arrangement is proved to be effective in minimizing cable force, deck displacement, and moment as compared to harp cable arrangement.
iii. The optimum side to main span ratio of cable stayed bridge structure is at 0.5 when provided with fan cable arrangement.
iv. Analysis of cable stayed bridge structures carried out the different soil type beneath each support, the response of the bridge may vary significantly. Girder moment, cables axial force, pylons shear, and pylons drifts are amplified up to 1.8, 1.4, 1.48, and 3.1 correspondingly in the worst load case.
v. There is scope to carry out research studies for determining optimum weight of cables and developed stresses in cable stayed bridges with respect to side to main span ratio and height of pylon of different cable arrangement in the cable stayed bridge structures considering different materials for cable stayed bridge, various loads such as dead load, live load (Class-AA) and wind load consider as per the Indian IS code IRC: 6-2016.

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