Effect of Cable Arrangement on Aerodynamic Stability of Cable Stayed Bridge

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Abstract- *Cable stayed bridges have good stability, optimum use of structural materials, aesthetic, relatively low design and maintenance costs, and efficient structural characteristics. So that, this type of bridges is becoming relatively more popular and are generally preferred for long span crossings compared to suspension bridges. With regards to cable arrangements, the most common type of cable stayed bridges are harp, semi fan and semi fan bridge. This parametric study is carried out to find the aerostatic effect on stability of a cable stayed bridge with respect to cable arrangements. In the present study, linear static analysis of cable-stayed bridge under the action of wind loading has been carried out for the three-different middle span length and three cable arrangements of cable. Angle of attack is also changed to examine various parameters. Analysis has been carried out using this software SAP 2000. Results in form of axial forces in deck, cable tension, deck deflection, axial force in pylon have been compared for the study of behaviour of cable-stayed bridge.*

Keywords- Cable stayed bridge, cable arrangements, aerodynamic analysis.

I. INTRODUCTION

Modern cable structural system that consists of girders, deck and pylon having compression and stay cables having tension. Typical cable one or more pylons erected above piers in the middle of the span. From these pylons, cables are stretch down diagonally (usually to both sides) and support the girder. Because the only part of the structure that extends above the road is the Cable stayed bridges have a simple and elegant look. The rapid growths of modern cable-stayed bridges throughout the world afterwards is due to the numerous advances in bridge engineering leading towards better understanding of the behaviour and performance and recognizing the advantages of this type of bridges in terms of economy, ease of construction and fabrication, aesthetics and the different possibilities in structural. A major concern in the structural efficiency of a cable-stayed bridge and, therefore, in its cost, lies in the symmetry of its longitudinal configuration, i.e., when the side span is roughly taken as the 40% of the main span for a three-span bridge. In this paper, a cable stayed bridge has a different longitudinal layout as harp, fan and is analyzed. In recent days the cable-stayed bridge has been recognized as a very efficient and competitive design for bridges of span ranging from 200m to 800m. The reinforced concrete girder design for the longitudinal bridge member is generally considered more economical for a span length of 200 m to 400 m. For a span length between 400m to 600m, the composite deck cross-section can be considered, whereas for 600m to 800m, the steel box girder or composite deck design is preferable. [1] Cable stayed bridges are exposed to lateral bending due to drag force, vertical uplift due to lift force and torsional bending due to pitch moment. The load applied on the deck and self-weight of deck is transferred through cable in tension through the pylon to the foundation.

Structural Cables are popular due to their Characteristics like light Weight, low damping and higher flexibility. They are easily excited and severely oscillate through dynamic effects of Wind. The cable Vibrations is coupled with the vibrations of the bridge girder and pylons.

In the present study, linear static analysis of cable-stayed bridge under the action of wind loading has been carried out for the three different middle span lengths of 210 m, 310 m, and 410 m and for three cable arrangements considering three angles of incidence of wind 0°, 5° and 10°.

II. DATA UNDERTAKEN FOR STUDY

Upper portion of pylon

Cross section	6.7 x 3 m
Thickness	0.5 m
Height	50 m for 210 m span 60 m for 310 m span 80 m for 410 m span

Lower portion of pylon

Cross section	7.3 x 5 m
Thickness	0.7 m
Height	20 m
Deck width	23.6 m
Depth	3.2 m

Cables of 0.2 m diameter are spaced at each 10 m of interval on deck. Based on the data taken for study total 27 model prepared in SAP2000. The arrangements of cables are taken as Harp, semi fan and Fan for each set of data are shown in figure.

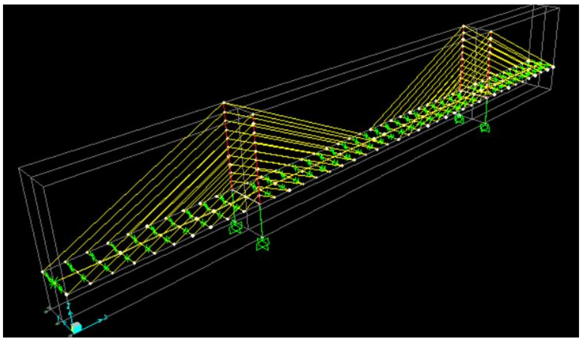
Fig 1 Harp arrangement

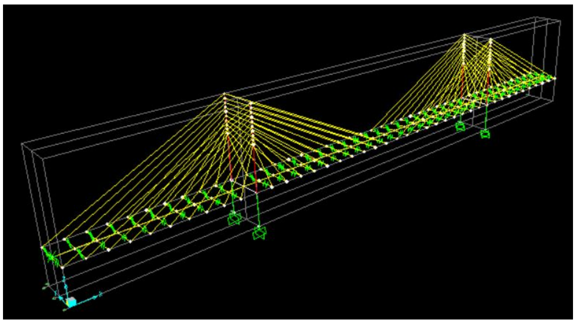
Fig 2 Semi fan arrangement

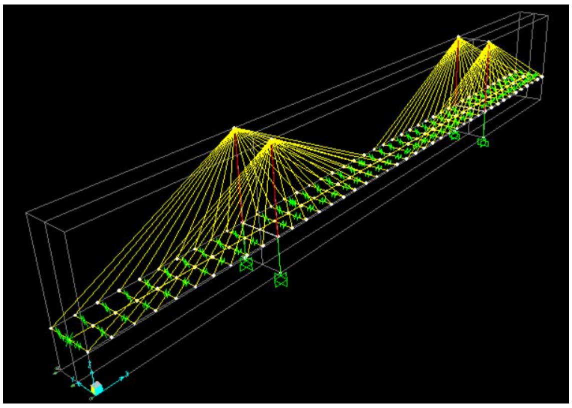
Fig 3 Fan arrangement

Mid span	**Span 210 m**	**Span 310 m**	**Span 410 m**
Length	410 m	610 m	810 m
Mid Span	210 m	310 m	410 m
Side Span	100 m	150 m	200 m

III. MODELLING IN SAP 2000

Deck

A box girder of concrete has to be modelled such as to behave correctly in bending and torsion and to resemble the inertia effects correctly. In order to achieve connection of girder with cables, rigid links are used in the direction perpendicular to the beam element. This is done to achieve the proper offset of the cables with respect to the centre of inertia of the spine.

Cables

Because of nonlinearities arises from the cable sag the modelling of cables is a difficult issue. Cables are modelled as linear frame element.

Pylon

Pylon modelling is done as beam elements. The pylon leg stretches at the pylon head, was divided into beam elements as long as the distance required in between the cable anchorage points.

IV. ANALYSIS OF CABLE STAYED BRIDGE

A. Aero Static Loads

A In this chapter, effect of cable arrangement on aero static analysis of cable-stayed bridges with central span of 210 m, 310 m and 410 m is analyzed. The harp, semi fan and fan type of arrangement is considered for analysis. Three angles of incidence of wind i.e. 0°, 5° and 10° are taken for study of effect of attack angle attack on various parameters. Basic wind speed taken as 39 m/s. Under the wind effect, the bridge is subjected to, and acts to resist Drag Force, Lift Force and Pitching Moment. Consider a section of bridge deck in a smooth flow, as shown in Fig. 6. Assuming that under the effect of the mean wind velocity V with an angle of incidence α_0. Then the effective wind angle of attack will be $\alpha = \alpha_0 + \theta$. Where θ is the torsional displacement of deck. The components of wind forces per unit span acting on the deck can be written in wind axes as,

Drag force $F_y(\alpha) = \frac{1}{2}\rho V_z^2 Cy(\alpha) D$

Lift force $F_z(\alpha) = \frac{1}{2}\rho V_z^2 Cz(\alpha) B$

Pitching moment $M(\alpha) = \frac{1}{2}\rho V_z^2 Cm(\alpha) B^2$

Where Cy(α) is the coefficient of drag force, Cz(α) is the coefficient of lift force and Cm(α) is the coefficient of pitching moment which is obtained from research paper. B is the deck width in m. D is the vertical projected area in m^2. ρ is the air density in kg/m3. Vz is the design wind speed in m/s. From above terminology, calculated drag and lift forces are applied on deck as uniformly distributed load while on the pylon the drag force is calculated as per the formula given in IRC 6:2014.

B. Live Loads Applied on Cable Stayed Bridge

During the parametric study, moving loads on cable-stayed bridges are taken as per IRC-6:2014 guidelines. This code defines the type of vehicle and number of vehicle for bridges. As per IRC-6:2014, tracked vehicle of class A which is standard vehicle is considered. According to IRC 6:2014 for the deck width of 23.6 m for the design purpose 6 nos. of lanes should be taken. So, six lanes of 3.75 m width on the top of concrete deck is generated in SAP2000.For the analysis purpose, linear static analysis has been done and load combinations are taken as dead + live, dead + live + wind positive, dead + live + wind negative.

V. PARAMETRIC STUDY

To find out best possible cable arrangement for given con-ditions, quantities like maximum tension in cable, axial force in pylon, axial force in deck, and central deck displacement were shown as bar chart for different configuration and different span with three angles of incidence of wind. The study was carried out for the elements which form which form major structural component i.e. cables, girder and pylon for linear static case.

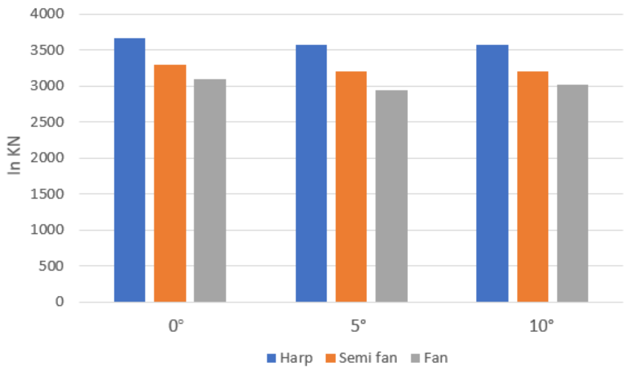

Fig 4 Axial force in cable for 210 m span

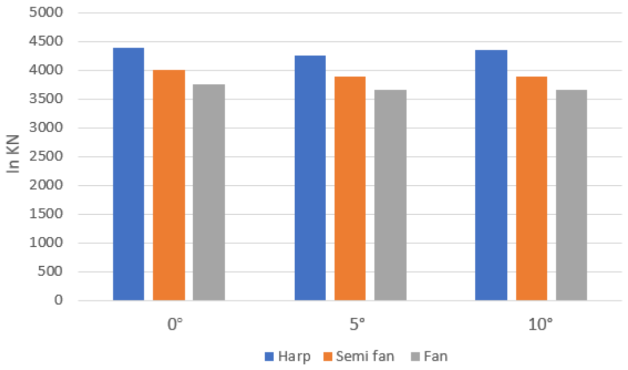

Fig 5 Axial force in cable for 310 m span

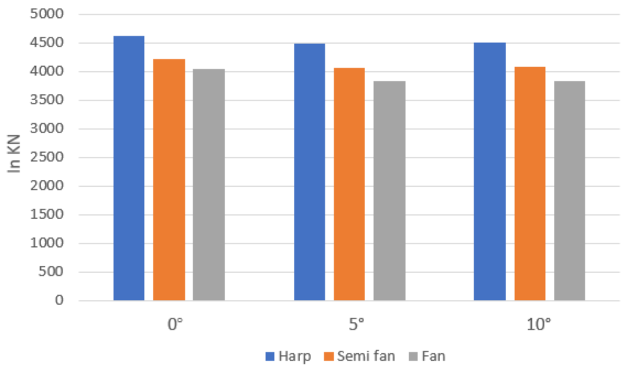

Fig 6 Axial force in cable for 410 m span

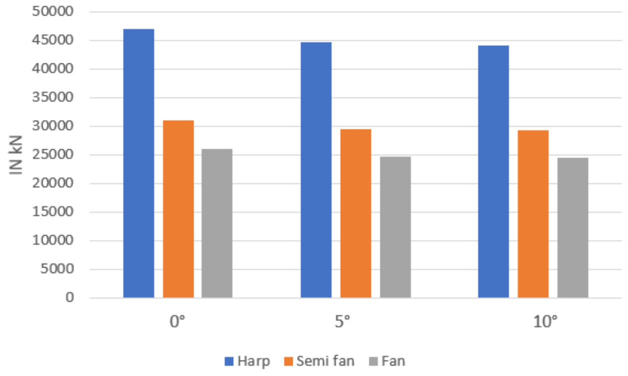

Fig 7 Axial force in deck for 210 m span

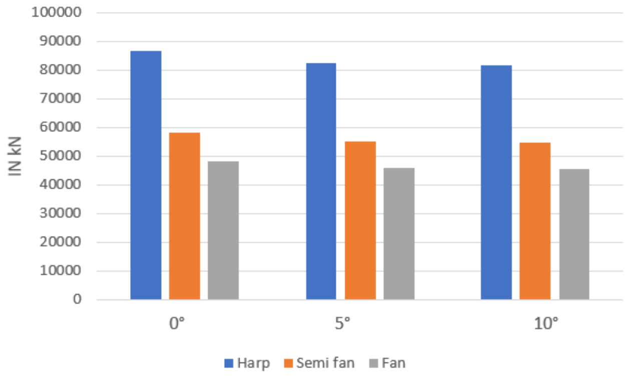

Fig 8 Axial force in deck for 310 m span

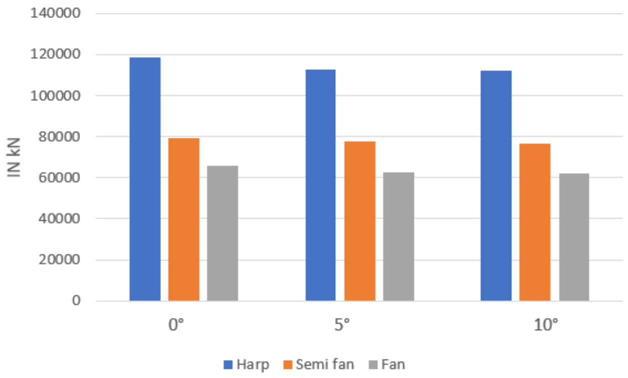

Fig 9 Axial force in deck for 410 m span

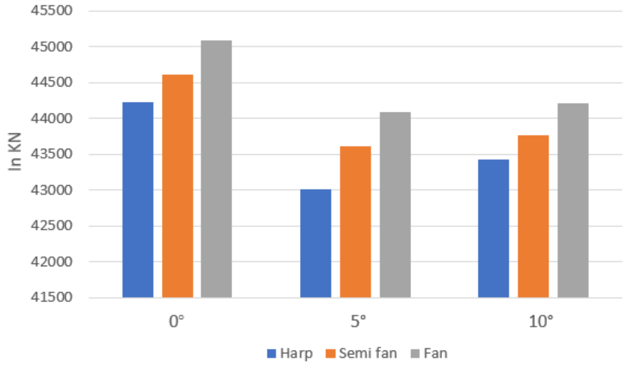

Fig 10 Axial force in pylon for 210 m span

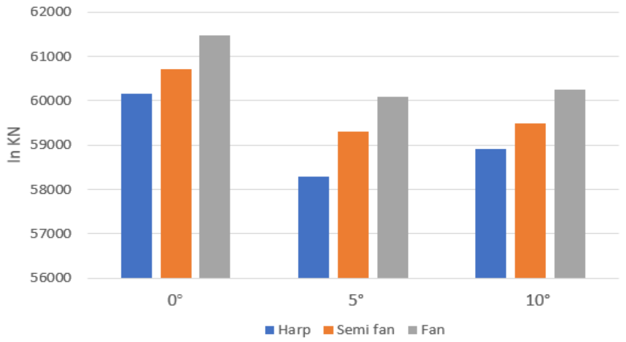

Fig 11 Axial force in pylon for 310 m span

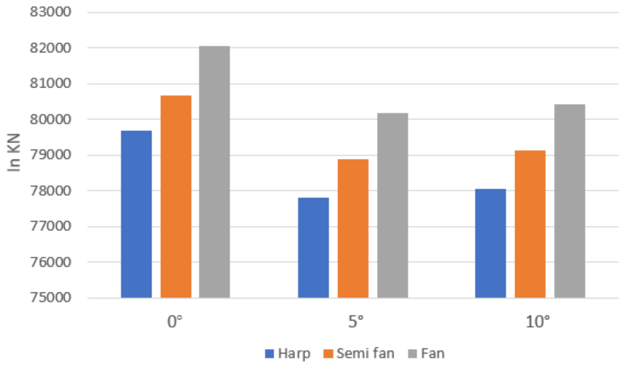

Fig 12 Axial force in pylon for 410 m span

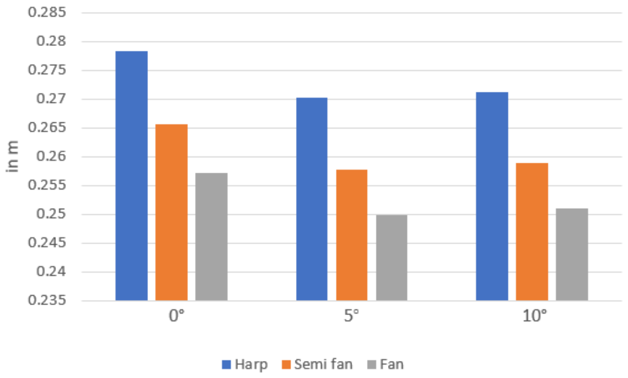

Fig 13 Displacement of deck for 210 m span

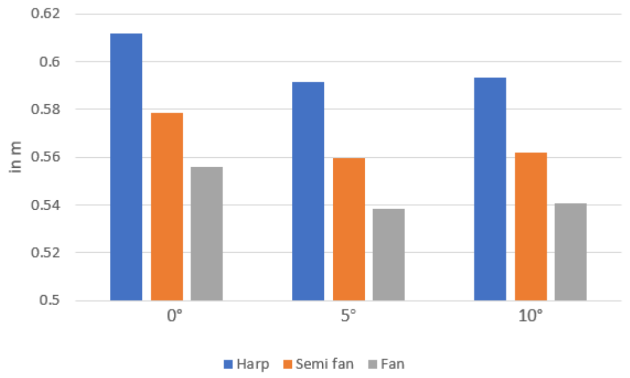

Fig 14 Displacement of deck for 310 m span

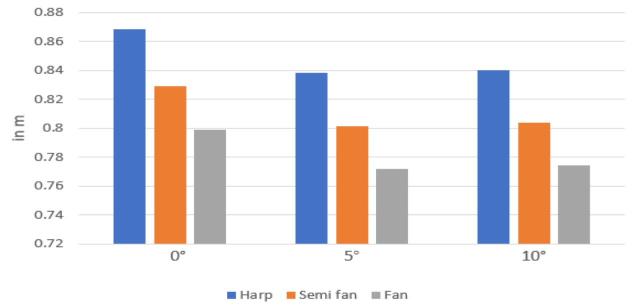

Fig 15 Displacement of deck for 410 m span

VI. CONCLUSION

- After analyzing cable stayed bridges under linear static loadings the biggest vertical displacement of deck was observed in harp type models and the smallest one was observed in fan type models.
- The biggest central displacement at the middle of deck in harp type models was 8.72% more than fan type and 4.81% more than semi fan type of cable arrangement.
- Total maximum axial force in the pylons in fan type model was 2.97 % greater than harp and 1.71 % greater than semi fan type models.
- Axial force in deck for semi fan type of models were observed less than harp type and greater than semi fan type models.
- As the angle of attack of wind increases from 0° to 5° initially forces in each element found to be decreasing and from 5° to 10° each parameter shows increase in value.
- The least cable forces among maximum tension forces obtained for each model were in fan type and greatest on were in harp type models.

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