The effects of Side Span Supports on behavior of long span Cable-Stayed Bridge

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Abstract- The long span bridge requirement is increasing with the rising traffic in the developed country. The resolution of the long span bridge can be provided by introducing high strength load resisting material for structural members. The cables can resists very large amount of tensile forces effectively and therefore preface of the cable supported structures. The long span cable supported bridge has been profoundly enhanced by the development of new structural materials and new methods of analysis. As the bridge span increases the bridge become more flexible and viable to dynamic loadings. The Cable supported bridges are more susceptible to nonlinear behavior. To study the behavior of the long span cable-stayed bridge having 1400m main span and 700m side span is studied. To enhance the structural stability of the bridge the side span supports are considered as the parameter to reduced the flexibility of the bridge. The analysis of the bridge is carried out to study the behavior of the bridge. Using Sap2000 v14.0.0 cable-stayed bridge was analysed. The vertical and lateral stability is presented in the form of the time period of the bridge in vertical and lateral direction.

Keywords – Cable-stayed bridge, Modal analysis, SAP2000, Time period

I. INTRODUCTION

There is a wide variety of structures which utilize high strength steel cables like cable supported bridges whether it is suspended, cable-stayed or hybrid. Cable supported roofs like stayed or supported on cables, trusses as well as nets, or air inflated, guyed masts, ropeways, antennae and cooling towers utilizing cable systems. (Krishna, P. 2001)

To use the cables as tension resistance structural members in bridges for provision of long span bridges, the structural systems generally used to achieve longer span are as listed below.

1. Cable-stayed bridge system,
2. Suspension bridge system,
3. Hybrid cable-stayed suspension system

Here Cable-stayed bridge system is considered to study the behavior of the bridge. Inclined cables of the cable-stayed bridge, support the bridge deck directly with relatively taut cables, which, compared to the classical suspension bridge, provide relatively inflexible supports at several points along the span. The nearly linear geometry of the cables produces a bridge with greater stiffness than the corresponding suspension bridge. The first known cable-stayed bridge was designed in 1784 by C.T. Loescher.

A. Fan System

According to the cable arrangement of the cables in the cable-stayed bridge, the bridge can be of various types. Here we have select the fan type of cable arrangement of cables in bridge. In the fan system, the anchor cable connecting the pylon top to the end support in the side span and plays a dominant role in the achievement of stability in the cable system. To utilize the anchor cable efficiently, it is required that this cable for any loading combination is subjected to a certain tension. The minimum tension in the anchor cable occurs for traffic load in the side spans only.

B. *Stiffening girder* (actions of the stiffening girder)

In contrast of the cable system where all elements have to be in tension, the stiffening girder will generally be able to transmit tensile as well as compressive forces. Thus, when the stiffening girder replaces some of the cable elements of the pure cable system, new possibilities of achieving equilibrium will exist.

In system (a) the stiffening girder is subjected at midspan to a horizontal tensile force H equal to the sum of the horizontal cable force components. This implies that the girder will be entirely in tension, and the forces of the system are consequently the same as found in the pure cable system. In system (b) the stiffening girder is subjected at the pylon to a horizontal compressive force H , and the girder will therefore be entirely in compression. This leads to the self- anchored system applied in almost every cable stayed bridge built up till now. In system (c) the stiffening girder is subjected to both a tensile force Hl at midspan and a compressive force Hr at the pylon. With Hl + Hr equal to the sum of the horizontal cable force components, the horizontal equilibrium will be fulfilled. As the midspan tension Hl has to be transferred to the soil at the ends of the stiffening girder, system (c) might be designated as a partially anchored system. The three systems of equilibrium can be created by the choice of the supporting conditions for the stiffening girder and the attachment of the anchor cable.

C. *Supporting Conditions*

Supporting conditions for the stiffening girder is assumed that the girder and the pylon pass each other without a direct connection. However, in cable stayed bridges system bearings are placed between the girder and pier below. With this system one of the bearings must be fixed longitudinally, and it is often chosen to make one of the pylon bearings fixed and the other longitudinally movable. The bearings under the pylons generally will be subjected to vertical forces of a considerable magnitude. In modern cable stayed bridges a compact neotop bearing is often used. For the movable bearing the neotop is supplemented by a sliding Teflon bearing.

Table -1 Constraint types of the deck

Support location	**Ux**	**Uy**	**Uz**	**Rx**	**Ry**	**Rz**
Tower	**0**	**1**	**1**	**1**	**0**	**1**
Pier	**0**	**1**	**1**	**1**	**0**	**1**
Abutment	**0**	**1**	**1**	**1**	**0**	**1**

II. CABLE-STAYED BRIDGE DATA

A. *Bridge Geometrical Data:*

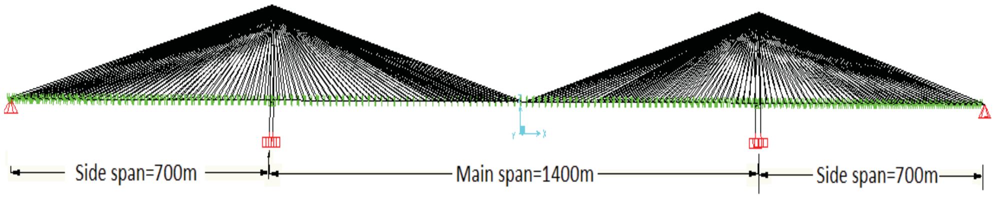

Figure 1 Cable stayed bridge with main span of 1400m and side span of 700m

As shown in the above Figure 1 cable-stayed bridge with main central span is 1400m and side span of 700m is provided. In ordered to improve the vertical bending stiffness of cable supported bridges, some subsidiary piers can be used in side spans (Zhang, 2006). To investigate the effect of the side span supports in 700m side spans, different cases can be considered and analyzed.

Numbers of intermediate side span supports considered and their locations considered in this study are as given in the following table 2.

Table 2 No. of intermediate side span supports and their respective locations in side span

No. of side span supports	**1**	**2**	**3**
Positions of side span supports	**350 m**	**233.33 m**	**175 m**

All the models of cable-stayed bridge having different numbers of intermediate side span supports (ISSS) as shown in the above table with variable length in between intermediate side span supports are shown in the Following Figures.

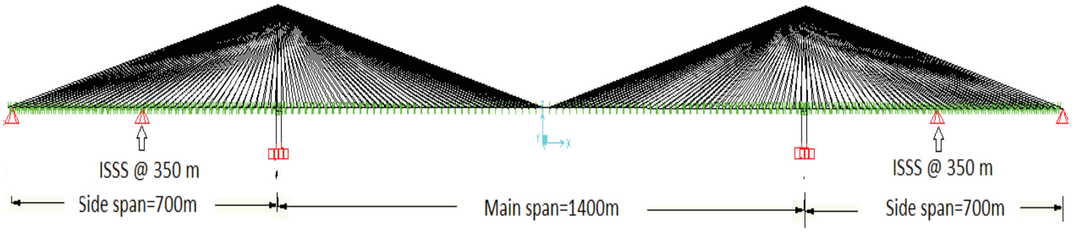

Figure 2 Cable stayed bridge with one ISSS in side span at 350m c-c

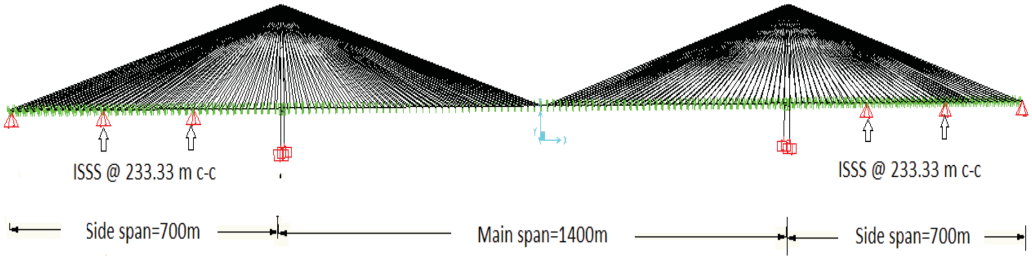

Figure 3 Cable stayed bridge with two ISSS in side span at 233.33m c-c

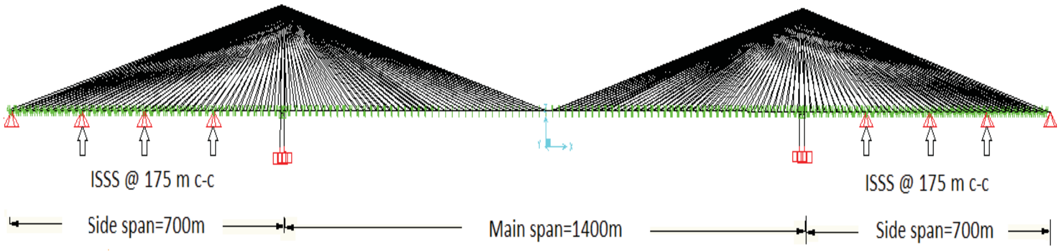

Figure 4 Cable stayed bridge with three ISSS in side span at 175m c-c

B. Bridge members cross-sectional property Data:

The cross sectional property of the members considered to study the behavior of the cable-stayed bridge for the analysis is presented for the various members of the bridge in Table 3.

Table 3 cross-sectional properties of the girder and tower of Cable-stayed Bridge (Zhang Xin-Jun, 2007)

Members	**E (Mpa)**	**A (m^2)**	**Ix (m^4)**	**Iy (m^4)**	**Iz (m^4)**	**M (Kg/m)**	**Jm ($Kg.m^2/m$)**
Girder	**$2.1x10^5$**	**1.2481**	**5.034**	**1.9842**	**137.754**	**18386.5**	**$1.852x10^6$**
Stay cable	**$2.0x10^5$**	**0.008**	**0.0**	**0.0**	**0.0**	**62.5**	**0.0**
Tower C	**$3.3\ x10^4$**	**30.0**	**350**	**320**	**220**	**78000**	**$5.7x10^5$**
Tower TB	**$3.3\ x10^4$**	**10.0**	**150**	**70**	**70**	**26000**	**$4.7x10^5$**

Where, A - Cross section area in m^2, E - Modulus of Elasticity; J_d - torsional Constat; I_x-Vertical Bending moment of inertia; I_y - Lateral Bending moment of inertia; I_z - Vertical Bending moment of inertia; M - Mass per unit length; J_m – mass moment of inertia per unit length.

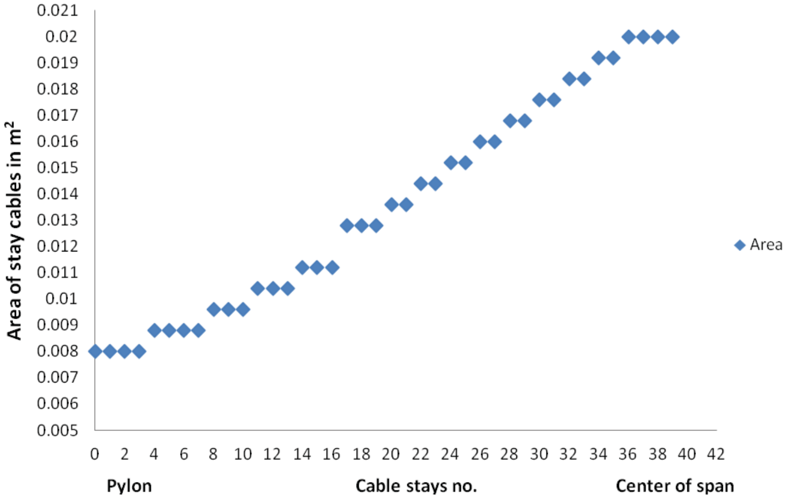

Figure 5 Area assigned to Stay Cables near pylon (cable-stays no. 0) to center of span (39)

Figure 5 presents the area of cable-stays with assigned cross sectional area in m^2 for various positions of the cables in the bridge near pylon to the center of main span.

C. Load Cases:

A load case defines how loads are to be applied to the structure, and how the structural response is to be calculated. Many types of load cases are applied. Structural elements of bridge are assigned with load cases which are shown in below Table 4.

Table 4 assigned loads to the different members

Type of the load	**Value of Assigned Load**	**Element Assigned**
Dead Load	**97.980 kN/m**	**Deck**
SIDL	**50.0 kN/m**	**Deck**
Live Load	**34.650 kN/m**	**Deck**

Static, dynamic and seismic analysis is carried out to study the behavior of the cable-stayed bridge. Here results are presented by considering parameters as the no. of intermediate side span support in the side span of the bridge.

III. RESULT PARAMETERS FOR PARAMETRIC STUDY

A. Effects of Intermediate side span supports in side spans

In order to improve the vertical bending stiffness of cable-stayed bridges, several subsidiary piers can be used in side spans (Zhang, et. al.2003). The effect of these subsidiary piers known as an Intermediate side span support (ISSS) on the cable-stayed bridge for the dynamic stability is analyzed. Here, the structures displacement parameters are considered for evaluation to study the feasible intermediate side span supports of cable-stayed bridge by analysis carried out. The dynamic modal analysis is carried out for comparison of Time periods of different mode shapes of cable stayed bridge with variable intermediate side span supports (ISSS). Time period of the bridge for different mode shapes like Lateral mode shapes, Vertical Mode shapes, longitudinal modes shapes with various no. of intermediate side span supports are also carried out. The bridge behavior for the stability analysis with different numbers of inter mediate side span supports are presented with following Tables showing the Time period of different mode shape.

B. Time period of Deck in Lateral Bending Mode

Time period of the deck in lateral direction represents the the strucutral rigidity of the bridge in that direction. The Table 5 presents the time period of the deck in lateral direction for first, second and third mode shape. The time period of deck in latereal direction is presented for various nos. of intermediate side span supports and respective length between two intermediate side span supports.

Table 5 Time Period of Deck Lateral Bending modes

No. of ISSS **At Distance**	**4** **0.25 Ls**	**3** **0.333 Ls**	**2** **0.5 Ls**	**1** **1 Ls**
1st Mode	**15.186**	**15.183**	**15.279**	**15.886**
2nd Mode	**5.256**	**5.285**	**5.373**	**6.367**
3rd Mode	**3.349**	**3.360**	**3.366**	**5.758**

Here in this model we have assigned different numbers of the Intermediate Side Span Supports, (ISSS) in side span. Here in X-axis the length between the ISSS are shown. If we have not assigned any ISSS to cable-stayed bridge than length is 1. If we have assigned 1 no of intermediate side span at the centre of side span than length between ISSS will be 0.5. for 3 no. of ISSS length is 0.333 and for 4 no. of ISSS the length between ISSS is o.25 as shown in Table5. Here, from Table 5 it is found that the lateral time period of the bridge is increasing with decrease in the length between ISSS. The lateral bending in the 1st mode is 4.4% without cable.

C. Time period of Deck in Vertical Bending Mode

The vertical bending mode for the deck of bridge is presented in Table 6. The Table is presenting the time period of the deck with different length of ISSS.

Table 6 Time Period of Deck Vertical Bending modes

No. of ISSS **At Distance**	**4** **0.25 Ls**	**3** **0.333 Ls**	**2** **0.5 Ls**	**1** **1 Ls**
1st Mode	**4.298**	**4.399**	**4.945**	**8.206**
2nd Mode	**4.141**	**4.200**	**4.464**	**5.951**
3rd Mode	**3.388**	**3.438**	**3.594**	**3.801**

The above data presents that time period is reducing drasticaly with changing assigned 4 no of ISSS. Here it is found that the time period is reducing to 52 % by assiging 4 no. of ISSS instead of Cable-stayed bridge without ISSS in 1st mode of vertical bending.

D. Time period of Pylon in Lateral Bending Modes

Table 7 Time Period of Pylon Lateral Bending modes

No. of ISSS **At Distance**	**4** **0.25 Ls**	**3** **0.333 Ls**	**2** **0.5 Ls**	**1** **1 Ls**
1st Mode	**12.851**	**12.942**	**13.017**	**13.109**
2nd Mode	**3.180**	**3.218**	**3.267**	**3.252**

Lateral bending mode of the pylon is presented in above Table7 with different lengths of the ISSS in side span of the cable-stayed bridge by providing various nos of the ISSS. The decreament in time period is found to be 2%.

E. Time period of Deck and Pylon simultaneously in Lateral Bending Modes

The deck and pylon both are simultaniously bending in the lateral mode shape. The combined deck and pylon lateral bending time period is presented in the following Table8.

Table 8 Time period of Pylon and deck combined lateral bending mode

No. of ISSS **At Distance**	**4** **0.25 Ls**	**3** **0.333 Ls**	**2** **0.5 Ls**	**1** **1 Ls**
1st Mode	**11.954**	**12.128**	**12.359**	**12.762**

The combined deck and pylon lateral bending time period is reduced by 6.3% as presnted in the above Table 8.

IV.CONCLUSION

From the analysis carried out with parameters considred as susidiary piers in side span the following points of discussion are took out:

1. By providing 175m, 233.33m and 350m distance between two intermediate side span supports in side span, the vertical bending mode time period of the deck can be reduce to 52 %, 54% and 60% respectively in respecte to 1st mode of vertical bending.
2. Reduction in the 2nd mode of lateral bending mode time period of the deck can be found up to 82.5%, 83% and 84.3% respectivey by providing 3, 2 and 1 nos. of the intermediate side span supports in side span.
3. The pylon lateral bendign mode is enhance minute and time period of the pylon can be reduce to 98%, 98.7% and 99.2% by providing 3, 2 and 1 nos. of the intermediate side span supports in side span respectively in 1st mode of lateral bending of the bridge pylon.
4. From the analysed models of cable-stayed bridge, It is found that with increasing the Intermediate Side Span Supports in side span the strucutral stiffness of the bridge can be enhanced significantly.

V. REFERENCE

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