Effect of Dynamic Load Analysis on Pylon Configurations of Cable Stayed Bridges

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ABSTRACT

Man's achievement in field of Structural Engineering is evident from world's largest bridge spans, tallest structures etc. In the recent years, cable stayed bridges have received more attention than any other bridge mainly, in the United States, Japan and Europe as well as in third-world countries due to their ability to cover large spans. Cable-stayed can cross almost 1000m (Tatara Bridge, Japan, Normandy Bridge, France) A study is carried out to find the dynamic effect on different shapes of pylons of a cable stayed bridge. The different shapes of pylons considered here are H type, A type, Spread pylon system with 19° and 30° spread. The central span of the cable stayed bridge is also varied as 700m, 850m, 1000m to study the combined effects due to shape and span. The study is carried out by taking live load according to IRC 6:2014, IRC Class A and Class 70R vehicle load was undertaken. A Dynamic analysis in the form of Linear Time-history is also carried out using El-Centro ground motion and various response quantities such as Bending-moment, Shear- force, Torsion and Axial force are represented.

Keyword: *El- Centro ground motion , Equivalent modulus of elasticity, Pylon Shapes.*

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1. Introduction

Man's achievements in structural Engineering are most evident in the World's largest bridge spans. Today the suspension bridge reaches a free span of almost 2000m (Akashi-Kaikyo Bridge, Japan) while its cable-stayed counterpart can cross almost 1000m (Tatara Bridge, Japan, Normandie Bridge, France). Cable-Stayed bridges, in particular, have become increasingly popular in the past decade in United States, Japan and Europe as well as one third-world countries. There is still place for innovation in Cable-Stayed Bridge techniques and the increase in their span length occurring during this last decade of the twentieth century is remarkable. The Cable - Stayed Bridge seems to be a developing bridge type at the moment. The German Engineer F. Dischinger (1949) rediscovered the stayed bridge, while designing a suspension bridge across the Elbe River near Hamburg in 1938. He recognized that the inclined cables of the early cable-stayed bridges were never subject to any initial tension, thus cables started to perform properly only after considerable deformations of the whole structure. In earlier development, this behaviour led to the misconception that this type of bridge was unacceptably flexible and consequently unsafe. During World War II, approximately 15,000 bridges were destroyed in Germany. The demand to rebuild these bridges was urgent. The requirements of efficient use of materials and speedy construction made cable- stayed bridges the most economical design for the replacements. The first modern cable-stayed bridge, the Strömsund Bridge designed by F. Dischinger, was completed in Sweden in 1955. The design and construction of this bridge represent the beginning of a new era of modern cable-stayed bridges. The rapid growths of modern cable- stayed bridges throughout the world afterwards is due to the many 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 fabrication and construction, aesthetics and the different possibilities in structural arrangements etc.

2. Problem description

Cable-stayed bridges with multiple stay cables are highly redundant structures. So SAP2000 is used as it is a powerful and versatile tool for analysis and design of structures based on static and dynamic finite element analysis.

In this paper cable stayed bridge having 700m, 850m and 1000m main span is modeled with four different type of pylon shapes i.e. A shape, H shape, spread pylon with 19° and 30° angle.

3. Modelling in Software

The finite element model of the bridge consists of three bridge components, i.e. deck, pylon and cable. The cables are modelled as truss element. The pylons and the deck is modelled as straight frame element. Figure 1 represents the overview of the three dimensional model of the cable stayed bridge. The deck accommodates 4 lanes of traffic. The side span length is half of the centre span length. The height of the tower from the deck level is 200m. Cables, spaced at 30 meters, suspend the girder.

3.1 Deck

A box girder of concrete is shown in the Figure 2 A modelling approach is used in which a single central spine of linear elastic beam elements that has the actual bending and torsional stiffness of the deck. Each of spine element beams has a length of 30m connected by cables at each ends. At these nodes rigid links are used to connect with the cable in perpendicular direction 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. Bridge deck section i.e. a box girder is modelled as a straight frame element.

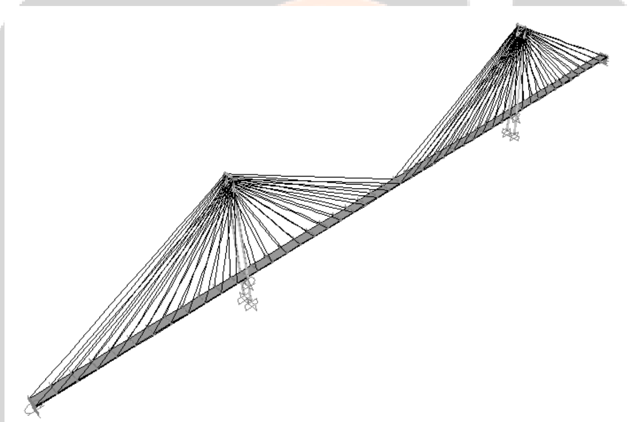

Fig-1: 3D model of cable stayed bridge

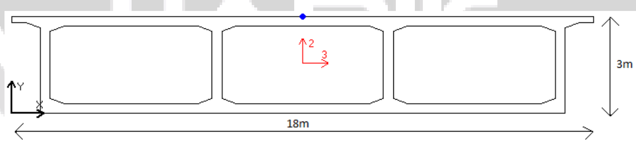

Fig-2: Cross section of pylon

3.2 Pylon

Hollow rectangular sections of steel are utilized for modelling the pylons. The cross section is as shown in figure 3.

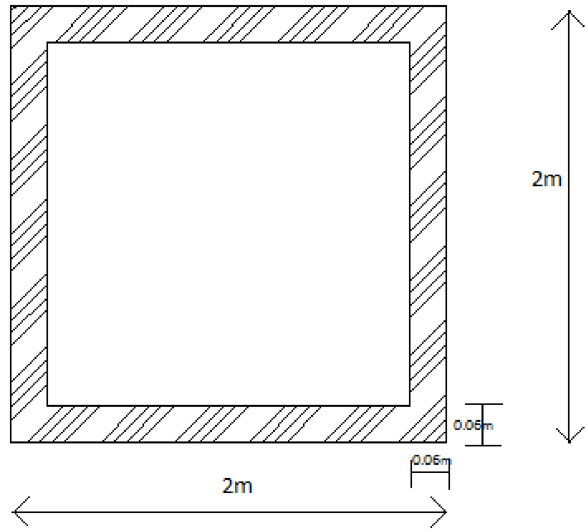

Fig-3: Pylon cross section

The cross section properties of girder and pylon are given below in Table 1.

Table – 1: Properties of finite element model

Properties	frame element	
	Girder	*pylon*
Cross section area A	$13.43m^2$	$0.46m^2$
M.I. I22	$354.48m^4$	$0.29m^4$
M.I. I33	$20.49m^4$	$0.29m^4$
Torsional constant J	$60.60m^4$	$0.44m^4$

3.3 Cable

Cable is converted in to rod model, with its sectional area alone being considered. The bending rigidity of cable is ignored. Converted modulus of elasticity Eeq by the equation of H.J. Ernst is used to consider reduction of rigidity due to influence of cable sag.

Cable initial tension is provided in cables to minimize the bending- moment and deflection of the deck under dead loads. The method used to determine the initial cable tension is Simple beam method. By applying the initial tensions, the vertical displacements of the bridge deck and the horizontal movement of the top of the pylons can be reduced up to 80%. In addition, the initial cable tension increases the moment carrying capacity of the deck. The cable areas, pretensions and Equivalent modulus are different for different spans.

3.4 The boundary conditions

The boundary conditions of finite element model are always hard to model precisely the same as those of real structures. The approximate boundary conditions must be taken in this project.

The connection between the pier and the pylons has been considered as fixed connection. The connection between the cables and the bridge deck has been considered to be pinned as cable shouldn't take the rotational resistances .

3.5 Loading conditions

Moving load analysis

In the present work is performed using IRC class A and IRC class 70R vehicular live loads. The vehicles are generated and applied in the existing lanes following the guidelines from IRC:6 (2014).

Dynamic Loading

Here a linear dynamic time-history analysis is done. The time history function of El- Centro ground motion has been taken. This graph is available in SAP 2000 software in time history folder.

4 Analysis and Results

Analysis cases and Combinations

4.1 Analysis cases

- Dead- consists of self-weight + pretension
- M1- consists of class A applied in all four lanes
- M2- consists of class 70R applied in Lane 1 and Lane 4
- M3- consists of class A applied in Lane 1 and Lane 2 and Class 70R applied in Lane 4.
- TH – Consists of linear dynamic analysis in form of Elcentro Ground motion.

4.2 Combinations

- Dead+ M1
- Dead+ M2
- Dead+ M3
- Dead+ TH
- Dead+ M1+ TH
- Dead+ M2+ TH
- Dead+ M3+ TH

4.3 Results

The various response quantities are determined for Cables, Girders and Pylons and are represented in graphical form. The various components here taken are the cable, girders and pylon which are the major structural component of the cable stayed bridge. Parametric studies are carried out for 700m, 850m and 1000m main span. For this four bridge models having different pylon configuration i.e. H-Frame, A-Frame, spread pylon with 19° and Spread pylon with 30° are generated and analyzed. The maximum response quantities such as Bending-moment, Shear-force, Torsion and Axial force are compared for all the four spans to find out best suitable pylon- configuration for a given condition. All the forces are in kN and all the moments are in kN-m.

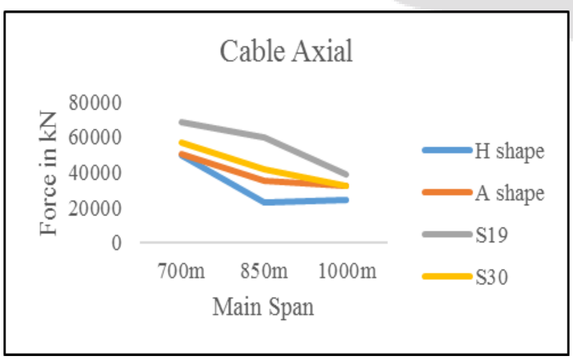

Chart 1: Axial force in cable

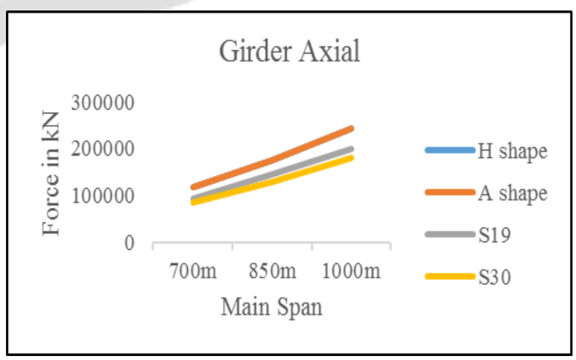

Chart 2: Axial force in Girder

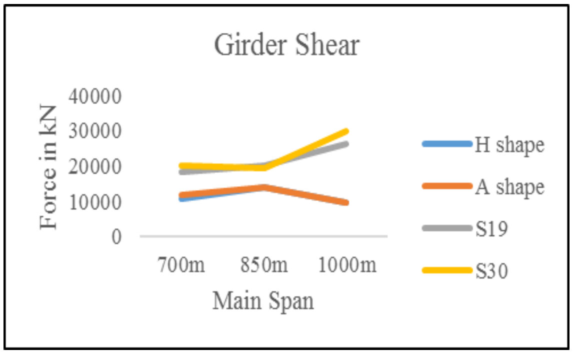

Chart 3: Shear force in girder

Chart 4: Torsional moment in girder

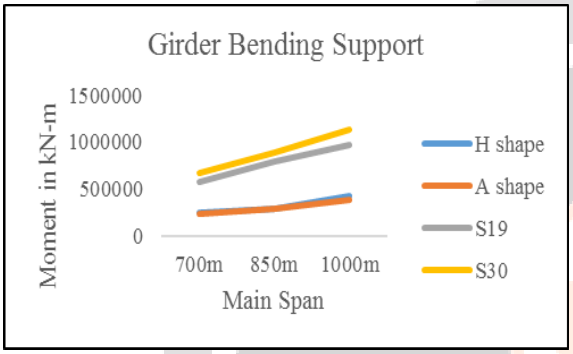

Chart 5: Bending moment(support) in girder

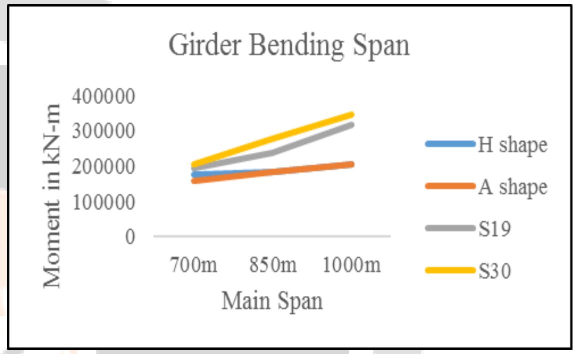

Chart 6: Bending moment(span) in girder

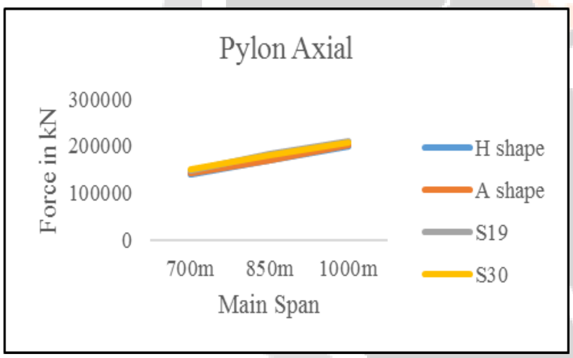

Chart 7: Axial force in pylon

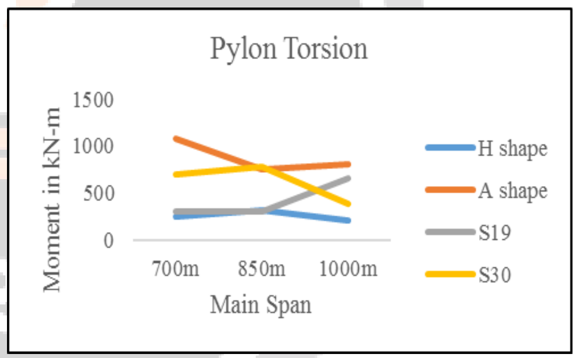

Chart 8: Torsional moment in pylon

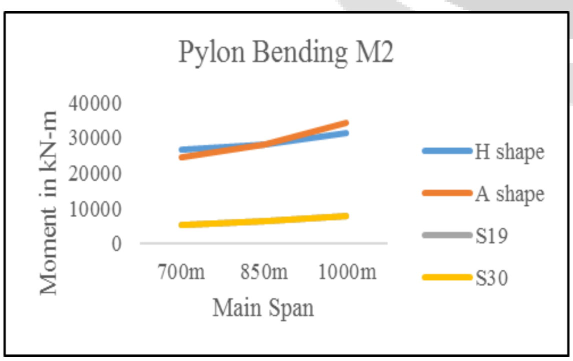

Chart 9: Bending moment M2 in pylon

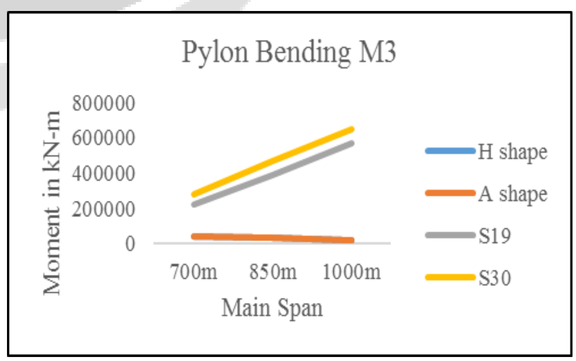

Chart 10: Bending moment M3 in pylon

5 Summary and Conclusion

5.1 Girder forces

- From the analysis results, it can be seen that the A shape pylon system gives lesser value of bending moment (span) than other systems for short spans but for higher span both A shape and H shape give lesser value than Spread pylon system. For the bending moment (support), A shape gives lesser value of all pylon system. Secondly there is drastic increase in case of spread pylon system.
- The torsional moment is found minimum for Spread pylon system and it's about 27% less than of H shape system.
- The axial force is found minimum for Spread pylon system which is about 25% less than of H shape pylon. Also the axial force continues to decrease as spread angle increases.
- The shear force values are nearly equal in H frame and A frame system and are very less compared to spread pylon system. A frame system is about 67% less than of spread pylon system.

5.2 Pylon forces

- The moment M3 – moment about transverse direction of bridge, is found minimum for A frame system and it is very low compared to Spread pylon system. i.e. 97% less that of spread pylon system for 1000m span
- The moment M2 – moment about longitudinal directions of bridge, is found minimum for Spread pylon system and it is 76% less than that of A frame system for 1000m span
- The torsional moment is found minimum for H frame system. It is 73% less than that of A frame system for 1000m span
- The axial force is found minimum for H frame system as compared to other systems but there is not much significant difference between values of other systems as it is only 5.5% less than that of spread pylon system.

5.3 Cable forces

- The cable tension is found minimum for H frame system as compared to other systems. It is 38% less than that of Spread pylon system.

Thus it can be said from present work that as far as girder forces are concerned Spread pylon system are advantageous. While pylon and cable forces are concerned, H frame system is advantageous of all four pylon systems. So it is not easy to predict which pylon configurations is best suited from dynamic analysis point of view.

6. REFERENCES

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