International Journal of Recent Technology and Engineering (IJRTE)
ISSN: 2277-3878, Volume-8 Issue-3, September 2019

Influence of Pylon's Geometry on response of Cable Stayed Suspension Hybrid Bridge (CSSHB)

J H Gabra, A. K. Desai

Abstract *: Cable-supported structures/bridges (CSB's) are used for surmounting across river, stream and sea o any obstructions spanning over for long to very long spans. Their ample stableness, optimal structural materials usage , esthetical appearance, relatively cheap design and maintenance, and greater efficiency is the backbone reason of its dominance.*
Designs of bridges vary contingent upon the reason it is intended to, function of the bridge, the nature of the terrain where the bridge is constructed and tied down, the material used to make it, and the assets available to build it and so on.
Cable Stayed Suspension Hybrid Bridge (CSSHB) has an added advantage additional bit of leeway in inclination over suspension bridge as well as cable stayed bridge. Dynamic investigation is is endeavored to inspect impact of pylon geometry (shape) on Modal Time Period(s) for different time history analysis using SAP2000. 1400 m span CSSHB has been used for the same. Fan type arrangement of cables is considered in this study Hexagonal shaped Pylon exhibits greatest flexibility followed by H, whereas Double Diamond shape, Inverted Y and A shaped pylons exhibit greater stiffness

Keywords *: Cable Stayed Bridge (CSB); Suspension Bridge (SB); Cable Stayed Suspension Hybrid Bridge(CSSHB),Pylon, Modal Time History Analysis (MTHA),SAP2000.*

I. INTRODUCTION

A. General

Bridges are critical lifeline services that ought to continue to be purposeful while not harm when associate degree earthquake to facilitate the rescue and alleviation operations would like of long span bridge has accumulated with boom of infrastructure. the want of unbelievable bridges of lengthy span is amassed after every passing day due to increase in population inhabiting and their desire, for recognition of bridges of long to super long spans, usage of material(s) with high to ultra high strength with innovative structural system is important.

Manuscript published on 30 September 2019
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In cable supported bridges for prolonged spans , the cable systems generally adopted may additionally be labeled into 1) Cable Stayed Bridges(CSB's) 2) Suspension bridges(SB's) 3) Combination of suspension and cable type …hybrid (CSSHB)

In normal to garner longer span bridges, CSB's and SB's are preferably selected/provided. This further led to evolution of more sophisticated Cable-stayed Bridge shot off absolutely in postwar Federal Republic of Germany within the early fifties. Since then, it has grown to be steadily well-known in numerous international locations thanks to its amazing structural efficiency as well as its esthetically desirable look.The fashionable bridge originated inside the eighteenth century once the event of the bridge structure and also the production of iron started out on a whole foundation these days, the bridge is most geared up kind for terribly long span bridge and definitely represents twenty or additional of all the longest span bridges within the world

Bringing in alongside the Combination of higher than 2 structural structures might bring domestic the bacon a genuinely long span CSSHB. CSSHB possesses superiority in preference SB's and/ or CSB's due to the fact it comprises advantages of each cable stayed nonetheless as suspension bridges.

B. Merits of CSSHB

Merits of the system formed by combination of the two systems namely CSB's and SB's can be endetailed as ::

1. In CSSHB, of span length of a similar SB, portion under suspension system is partly supplanted by cable-stayed system thereby suspension portion is shortened; so the axial tension forces in the main caternary cables are substantially reduced .
2. This reduced suspension system in main span leads to lowered cost of construction of the main cables and thereby the anchors.
3. Similarly, In CSSHB, of span length of a similar CSB , the cable-stayed part is also greatly shortened. This benefits us as , as it leads to lowering of Pylon height , length of cable stays and the axial forces in the deck.
4. In addition to these, moreover as the span of the cantilever part is minimized, yields a better stability to the bridge against the wind improving the stability

Thus, CSSHB beams out as an lucrative alternative as far as the design of bridges over long to super long spans

The figure 1 below shows the comparative sketch of three types of bridges

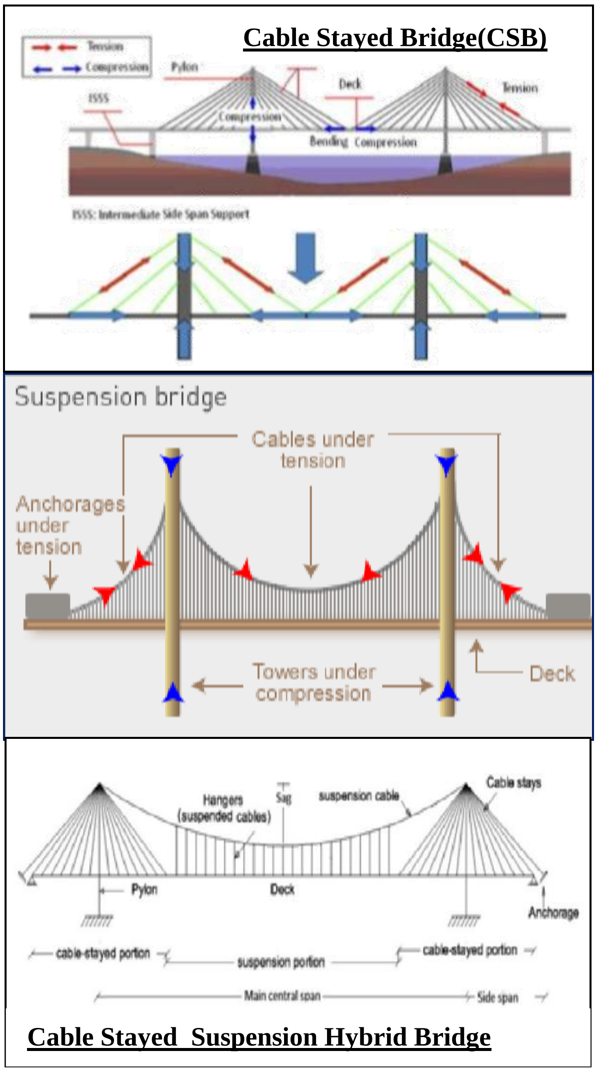


Figure 1:: Sketchmatic Representaion of Bridges

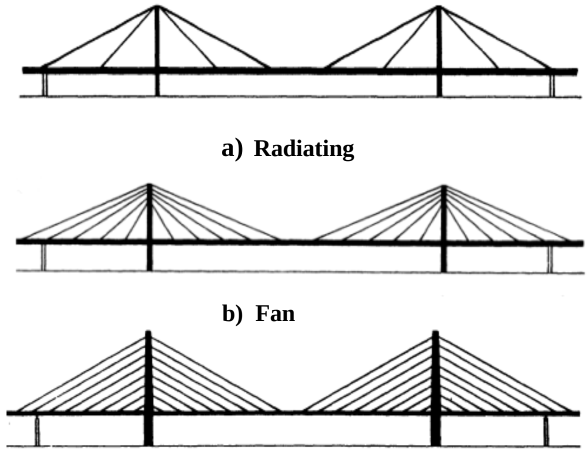
Major superstructure components of CSSHB can be enlisted as :::

1. Cable System
   a. Cable stays (main cable)
   b. Suspension cable (main cable)
   c. Hangers (suspended cables)
2. Pylon tower (with transverse beams)
3. Deck (Stiffening Girder)
4. Anchorage

C. Cable Systems

The cable systems can be sub classified based on

1. Longitudinal arrangement of the stay cable arrangement
   a. Radial system
   b. Fan system
   c. Harp system
2. Spatial arrangement of cable system
   a. Single vertical plane system
   b. Two vertical plane system
   c. Inclined plane system

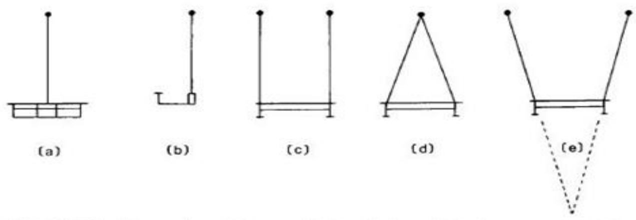


a) Radiating

b) Fan

c) Harp

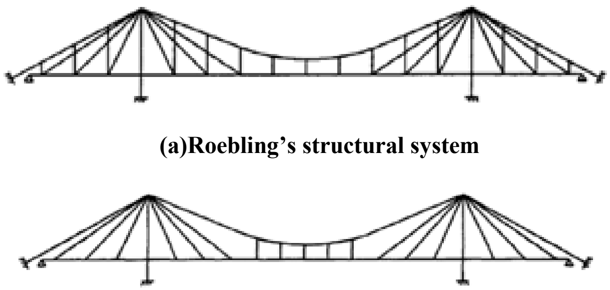
Figure 2:: Longitudinal arrangement :: Cable Stays



a) Single –plane vertical b) Laterally displaced vertical cDouble-plane vertical d) Double –plane inclined e) Double plane V shaped

Figure 2:: Arrangement of cable planes

In case of CSSHB ,John A. Roebling, in the 19th century provided a wheel changing great contribution to the Brooklyn Bridge, as he suggested installation of stay cables in the suspension bridge to reduce the displacement of the girder (Fig.4a). Similarly German engineer F. Dischinger improved the concept by eliminating the vertical hangers in the cable-stayed parts (Fig.4b) in the 1930s (These hangers are called cross hangers hereafter).



(a)Roebling's structural system

(b) Dichinger's structural system

Figure 4:: Structural System (Sun et al., 2013)

II. LITERTURE SURVEY ::CSSHB

Zhang and Sun Bin-Nam (2004) carried out three dimensional nonlinear aerodynamic stability analysis of cable stayed suspension Hybrid bridge span of 1400 m. They studied the effects of cable sag, length of suspension portion, cable arrangement on the aerodynamic stability of the bridge.

International Journal of Recent Technology and Engineering (IJRTE)
ISSN: 2277-3878, Volume-8 Issue-3, September 2019

Lai et al. (2004) conducted study to investigate the efficiency of isolation system for retrofitting cable stayed bridges

Zhang Xin-Jun (2007) presented the mechanics performance including the static and dynamic characteristics of cable-stayed suspension Hybrid Bridge

Zhang Zhe et. al. (2009) discussed the limit span of self-anchored cable-stayed suspension bridge. The limit spans of self-anchored cable-stayed suspension bridges with concrete girder or steel girder under vertical static load were discussed in detail based on the material strength and commonly used materials

Zhang Zhe et.al. (2010) presented "A static analysis of a self-anchored cable-stayed- suspension bridge with optimal cable tensions".

Siddharth Shah et al (2010) presented Effect of Pylon Shape on seismic response of Cable stayed bridge with soil structure interaction

Lonetti P. & Pascuzzo A. (2014) published a numerical model for considering the damage and failure behaviour on the cable system, which can be utilized for obtaining the response of hybrid cable-stayed suspension bridges subjected to moving loads.

Savaliya et al. (2015) carried out "Static and dynamic analysis of CSSHB having central span of 1400m and side spans of 319m each" ,using SAP2000 software.

Savaliya et al. (2015) studied" Effects of support Conditions on Static Behavior of 1400m main span and 700 m side span cable-stayed Bridge".

Savaliya (2016) thesis on "Effects of Geometrical on static and dynamic behavior of CSSHB"

Parekh et al. (2016) investigated the "Seismic response of Pandit Dindayal Upadhyay cable stayed bridge isolated with Friction Pendulum System (FPS) and Triple Friction Pendulum System (TFPS)", on Tapi River at Surat. The dynamic analysis was carried out by using SAP2000 software.

Seismic analysis of cable stayed bridge with different pylon shapes

Ashish m. jariwala et al(2017) studied "Seismic analysis of cable stayed bridge with different pylon shapes"

Anjali Palheriya et al (2018) reviewed about "Analysis of Hybrid Form of Cable Stayed and Suspension Bridge"

Parth K Patel et al (2019) studied " Effect of Multi-Support Excitation on CSB and CSSHB"

III. PROBLEM STATEMENT :: CSSHB

A. Introduction to the software

In the present study, the software used is SAP2000 v 19.2.1. It is a product of CSI,Berkely,USA.

It is used for analyzing general structures ranging from bridges to stadiums, dams to industrial buildings, offshore to onshore structures, soil etc. It has fully integrated programme that allows model creation, editing(modification),execution of the analysis, design optimization, review of results etc from within a single interface

SAP 2000 is a comprehensive and integrated design and finite element analysis Tool

It offers features like

- Multiple Coordinate system
- Powerful graphical display
- Frame, Cable & Shell structural elements
- Wide range and variety of loading options including loading functions of Time History, Response Spectrum etc.
- Static & Dynamic Analysis
- Linear & Non-linear Analysis
- Dynamic Seismic Analysis & Pushover Analysis
- Geometric Nonlinearity including P-δ effect
- Nonlinear Link & support analysis
- Frequency dependent link & support properties

B. Problem Studied

In the present study a CSSHB similar to that of bridge of East channel of Lingding Strait in China is considered.

The CSSHB configurations considered in the current study can be summarized as ::

- Main central span,L =1400m
  (with a central suspension span = 612m)
- Side spans = 319 m
- Pylon height ,h =258.986 m.
- Cable Sag to Span Ratio = 1/10
- .
- Deck = a steel streamlined box steel girder of 36.8 m width and 3.8 m height.
- The lateral spacing of two main cables is 34 m, and the interval of hangers is 18 m. The stay cables are anchored to the girder at 18 m intervals in the central span and 14 m in the side spans

The behaviour of the CSSHB is studied for various pylon shapes (variation in geometry) keeping other parameters constant

The geometric configuration of CSSHB is shown in Figure 5. Geometrical details

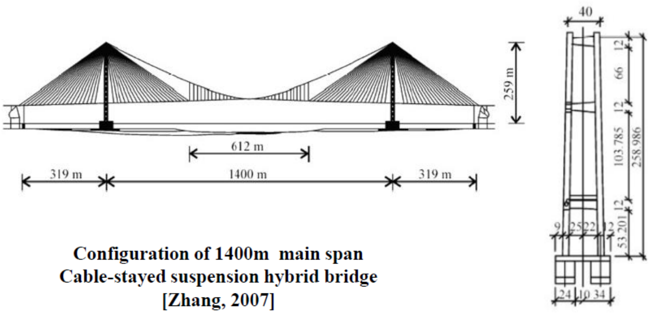


Figure 5:: Lingding Strait Bridge (China) Bridge[1]

C Modelling

C.1 Structural Components of the Bridge

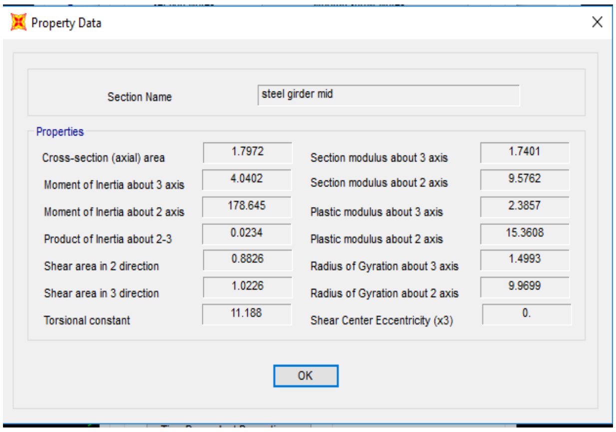
CSB like any other structure is divided in 2 main components namely Super-structure and Sub-Structure. For Finite Element Modelling of CSB, propertiesof material used and sections considered are entabulated in subsequent tables below

The finite element is developed using properties of material and section entabulated in **Table I**

Table I: Material used and Cables considered

Property	Steel	Concrete
Modulus of Elasticity (*E*)	2.0×10^{8} kN/m^{2}	3.354×10^{7} kN/m^{2}
Unit Weight	76.973 kN/m^{3}	24.993 kN/m^{3}
Poisson's ratio (μ)	0.3	0.20
Shear Modulus (G)	1.115 x10^{6} kN/m^{2}	1.397 x 10^{7} kN/m^{2}
Coeff. Of Thermal Expansion (α)	1.17 x 10^{-5}	0.55 x 10^{-5}

Cable No.	Diameter (m)	Area (m^{2})	Cable weight (kN/m)
Hanger	0.0903	6.4 x 10^{-3}	0.493
Main Cable (SS)	0.635	0.367	28.238
Main Cable (CS)	0.672	0.3547	27.302
Stay Cable	0.1009	8.00 x 10^{-3}	0.615



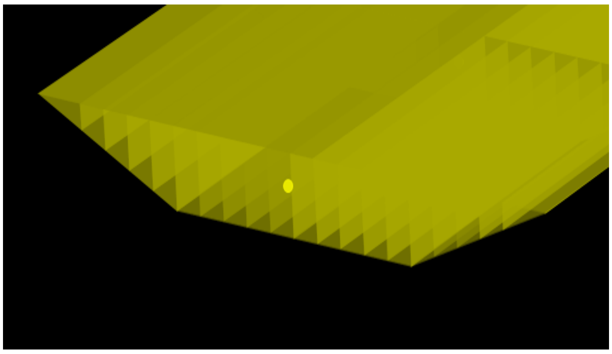


Figure 6:: Bridge Girder

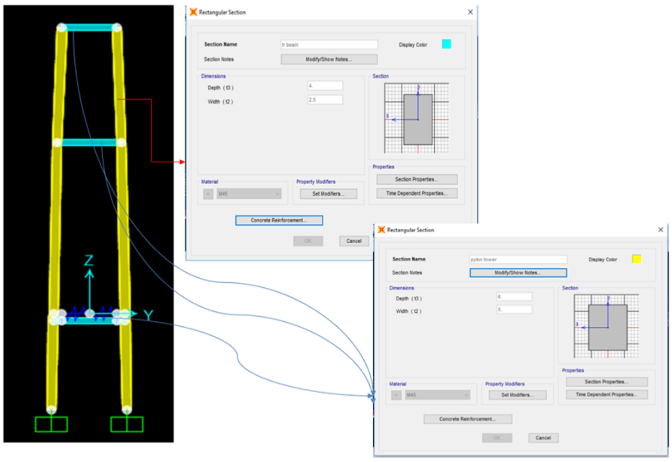


Figure 7:: C/s for Pylon & transverse Beams

Assignment of Bridge Elements

Girder :::: Modelled as frame elements, using steel as material, with thin plate enclosures

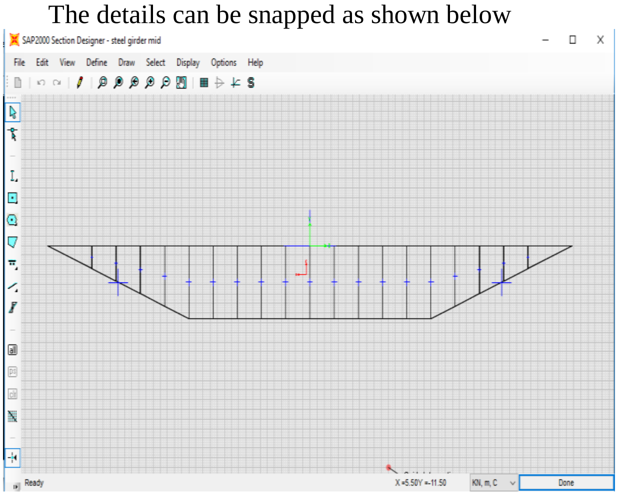
Pylon :::: Modelled as a frame element , using concrete as material, 7.5m x 4.0m in c/s, 258.986m high Pylon has transverse beams along its height

Transverse Beam :::: Modelled as a frame element , using concrete as material, 4.0m x2.5m in c/s

Cables :::: Modelled as a cable element

Supports, & Links :::: Modelled in accordance

The details can be snapped as shown below



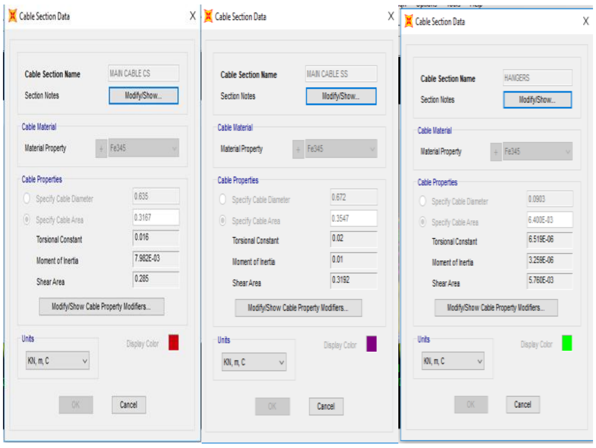


Figure 8:: Cable sections

C.2 Various Pylon Shapes

In the study , cases for different pylon shape for CSSHB are considered namely A type, Delta type , Diamond and Double Diamond type, H type ,Hexagonal type, Inverted Y type using the c/s and material as entabulated and figure in 3.01 above. The geometries generated are shown in figure 9 below

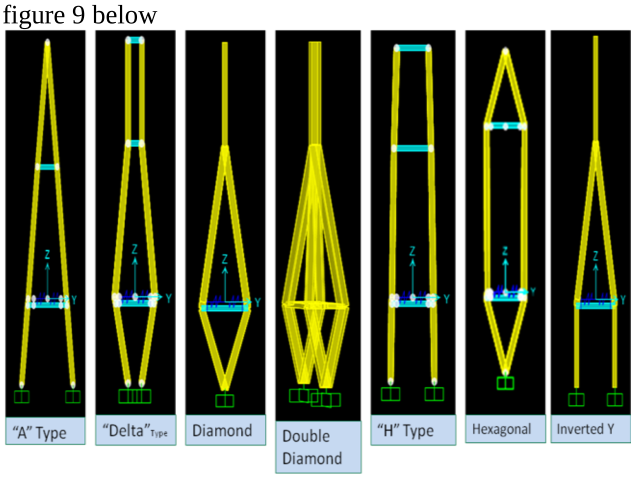


Figure 9:: Various Pylon Shapes analysed

D Load Assignments

Load assignments considered are::::

- Deck element is subjected to a
  - Dead load of 97.98kn/m
  - Side Induced Dead load of 50 kN/m
  - Live load of 34.65 kN/m

IV. Analysis and Results

A. Analysis

For evaluation of the seismic response of cable stayed suspension hybrid bridge(CSSHB), six near fault ground motions (seismic input data) namely , Imperial valley(1979), NewHall(1994), Lander(1994) , Bhuj (2001), Chamoli(1999) and Uttarkashi (1991) are used for the study on CSSHB. The acceleration displacement time history of all the ground motions used in study for 5 % damping. **Table II** shows the magnitude, Peak ground acceleration (PGA), Pear ground velocity (PGV) and Peak ground displacement (PGD) for near fault ground motion. For this purpose, MTHA was performed out for recognition of the dynamic behavior of bridge. It is evident that every mode has a mode shape aided with a set of modal properties like Time periods and Frequencies of the structure. Observations wrt change in geometry of Pylon Tower (different pylon shapes) are noted for the CSSHB

Table II :: Near fault earthquake data

Near-fault earthquake ground motions	Recording station	Duration (sec)	PGD (m)	PGV (m/sec)	PGA (g)
Imperial Valley, California (15.10.1979)	El Centro Array #5	39.420	0.765	0.98	0.37
Northridge, California (17.01.1994)	Newhall	60.000	0.381	1.19	0.72
Imperial Valley, California (15.10.1979)	El Centro Array #7	36.900	0.491	1.13	0.46
June26 ,2001 Bhuj ,India (26.06.2001)	Ahmedabad	109.995	0.088	0.11	0.13
Chamoli (29.03.1999)	Roorkee	44	0.108	0.04	0.06
Uttarkashi (20.10.1991)	Almora	21	--	0.01	0.021

B. Result(s)

Comparison of Modal periods as analyzed by various researchers are tabulated in **Table III** below followed by **Figure 10**

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DOI:10.35940/ijrte.C6042.098319
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Table III :: Comparison of Modal Period by different researchers (H type Pylon)

Modes		Zhang,2006		Sevaliya,2015		Our Results,2018		Difference % wrt Sevaliya	
Type	Shape	T (sec)	F (Hz)	T (sec)	F (Hz)	T (sec)	F (Hz)	T (sec)	F (Hz)
Lateral Bending	1-S	14.51	0.0689	13.14	0.0761	13.09	0.0764	-0.38	+0.39

Effect of Pylon shape on Modal periods is figured in **Figure11** and the same is tabulated in **Table IV**

Table IV :: Modal Periods for different Pylon Shapes

	Shape--->	Time Period ,T sec						
		A	Delta	Diamond	Double Diamond	H	Hexagonal	Inverted Y
Mode	1	12.494	13.552	13.951	12.055	13.089	14.974	12.717
	2	9.623	9.619	9.629	9.622	9.587	11.812	9.628
	3	7.571	8.480	8.702	7.553	8.371	10.185	7.583
	4	6.799	7.845	7.846	6.804	8.093	9.631	6.795
	5	6.089	7.550	7.583	6.087	7.539	7.589	6.121
	6	5.972	6.832	6.795	5.928	6.848	6.802	5.963
	7	5.193	6.126	6.085	5.193	6.139	6.081	5.414
	8	5.116	5.933	5.962	5.101	5.866	5.974	5.139
	9	4.563	5.085	5.138	4.571	5.107	5.142	4.633
	10	4.119	5.011	4.946	4.352	5.024	5.100	4.565

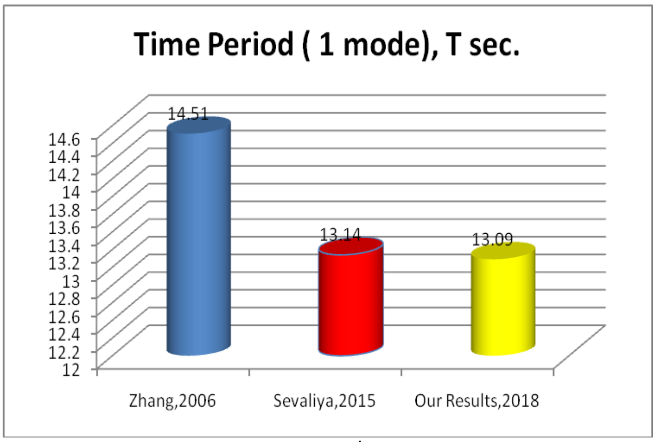

Figure 10:: Time Period-1st Mode:: H type Pylon

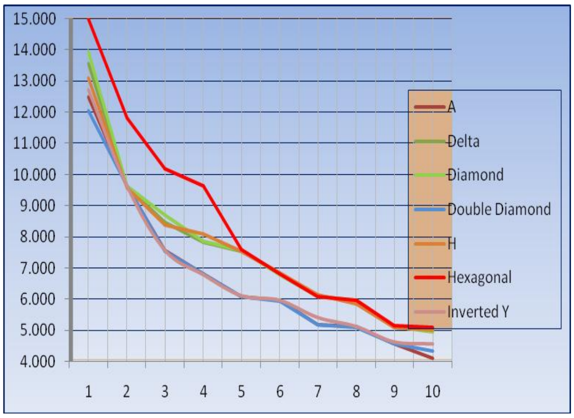

Figure 11:: Modal Periods for Various Pylon Shapes analysed

Conclusion

On analyzing the effect of Pylon shapes of the dynamic analysis (Time History) carried out on CSSHB, with 7 different pylon shapes, using SAP2000 , it can be observed and noted that . It concludes that the shape of pylon plays an important role in transverse seismic response of cable stayed suspension hybrid bridge(CSSHB)

1. For 1st mode , Hexagonal shaped pylon exhibits greatest time period whereas Double diamond shaped Pylon possesses least Time period. However the variation is of the range of 20%
2. Except for Hexagonal shaped Pylon, upto 3rd mode , All pylon shapes have almost same Time Period (with a slight variation of approx 5%)
3. 5th mode onwards , H shaped and Hexagonal shaped Pylons exhibit almost same frequency, and rest are almost same.
4. Thus Hexagonal shaped Pylon exhibits greatest flexibility followed by H, whereas Double Diamond shape, Inverted Y and A shaped pylons exhibit greater stiffness

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