

## Seismic response of cable stayed bridge with different types of pylons of various heights

<sup>1</sup>Shekhar S Patil, <sup>2</sup>Jayant P Patankar

<sup>1</sup> Post-Graduate Student, Department of Applied Mechanics, Walchand college of Engineering, Sangli, Maharashtra, India

<sup>2</sup> Professor, Department of Applied Mechanics, Walchand College of Engineering, Sangli, Maharashtra, India

### Abstract

Cable stayed bridge are getting more popular these days because of good stability and elegant for long span bridges compared to other types of bridges. A cable stayed bridge is a bridge in which the weight of the deck is supported by a number of cables running directly to one or more towers. Here focus is given on the effect of various shapes of pylons such as Single pylon, A type pylon and Inverted Y type pylon on the seismic response of cable stayed bridge. The effect of various heights of pylons on the seismic response of cable stayed bridge also taken in account for study.

The bridge span dimensions and other parameters are kept constant and only variation in shape and height of pylon is done for comparative study of pylon. The 3D bridge model is prepared on Midas Civil and linear dynamic analysis is carried out. The bridge response in terms of cable forces, pylon deformation, deck deformation, time period and base shear is obtained. It is found that, Single pylon and Inverted Y type pylon are better than A type pylon for parameters cable forces, pylon and deck deformation. Single pylon is stronger in longitudinal direction in resisting earthquake force while Inverted Y type pylon is stronger in lateral direction in resisting earthquake force.

**Keywords:** cable stayed bridge, shape of pylon, height of pylon, midas civil, earthquake force, linear dynamic analysis

### 1. Introduction

Bridges are critical life-line facilities which should remain functional without damage after an earthquake to facilitate the rescue and relief operations. In recent years, several cable-stayed bridges have been constructed, which results in a great demand to evaluate the effects of seismic behaviour of the bridges, and properly reflect it in their seismic design.

In this paper, different types and heights of pylon are studied for cable-stayed bridge. To know behaviour of cable stayed bridge when all parameters are staying constant except pylon shape and height; this study is required. Pylon is a column that is connected with all cables and transmits cable's forces to foundation. By changing the height of column, it will also change the inclination of cable.

### 2. Details of the models studied

To observe behaviour of bridge by changing shape and height of pylon, we have to fix other parameters of bridge. Fixed parameters of bridge are Bridge span is 150m, width of deck is 21m (four lane), Pylon mass, cable connection at 1.5m from top. Variables of cable stayed bridge are pylon shape and height. For 150m long bridge, Shapes of pylon considered are Single pylon, A type pylon and Inverted Y type pylon. The height of pylon is Span/6 to Span/3.75 i.e. 25m to 40m (Total height of pylons are 60m to 75m). In this paper, different height of pylon is taken; Total Heights are 60m, 65m, 70m, 72.5m and 75m.

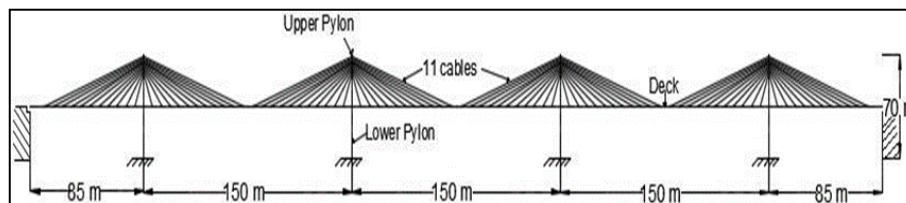


Fig 1: General layout of cable stayed bridge

Table 1: General details of cable stayed bridge

Bridge type	Five span continuous cable-stayed bridge	
Span	$L = 85\text{ m} + 150\text{ m} + 150\text{ m} + 150\text{ m} + 85\text{ m} = 620\text{ m}$	
Tower or Pylon Height	a	60 m
	b	65 m
	c	70 m
	d	72.5 m
	e	75 m
Bridge Width	B = 21 m	
Lanes	4 lane structure	

The details about the bridge type, span, pylon height, bridge width and lanes of bridge are given in table 1.

**Table 2:** Section Properties

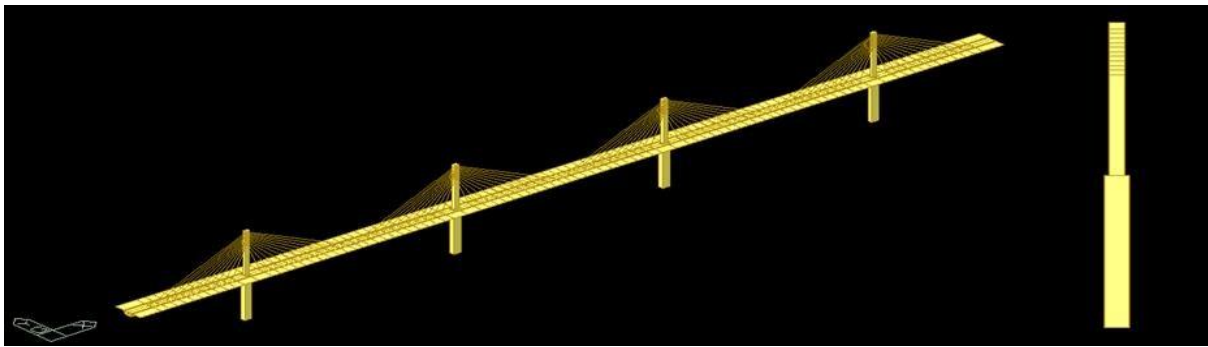
Section`			Property
Deck (Box Girder)		Support	M 60
		Other Sections	M 50
Pylon	5m*3m	Lower Pylon	M60
	3m*2m	Upper Pylon	
Cable	21 T 15	3 Cables	BS5896-Y1860S7-15.7
	26 T 15	4 Cables	
	30 T 15	5 Cables	

**3. Modelling in Midas**

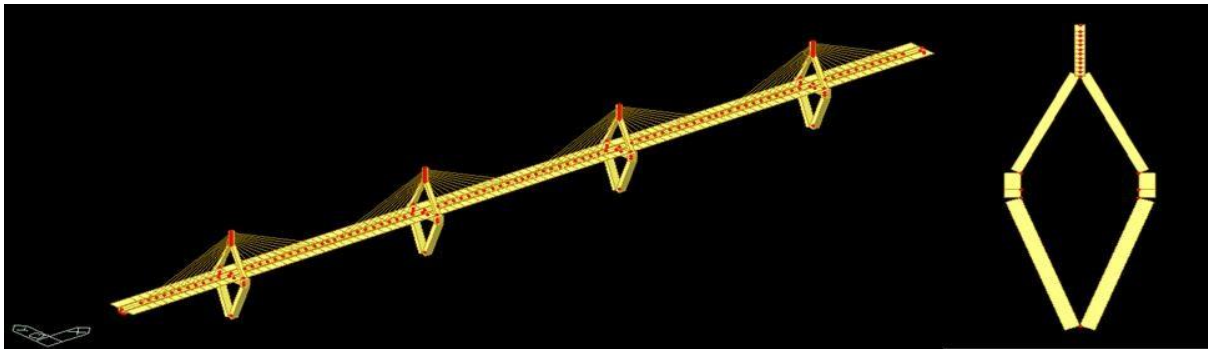
The cable stayed bridge is modelled in MIDAS Civil by using details listed in table 1 and 2 and the layout of cable stayed bridge as shown in figure 1. The details about the bridge type, span, pylon height, bridge width and lanes of

bridge are given in table 1. The section properties used in modelling of cable stayed bridge are listed in table 2.

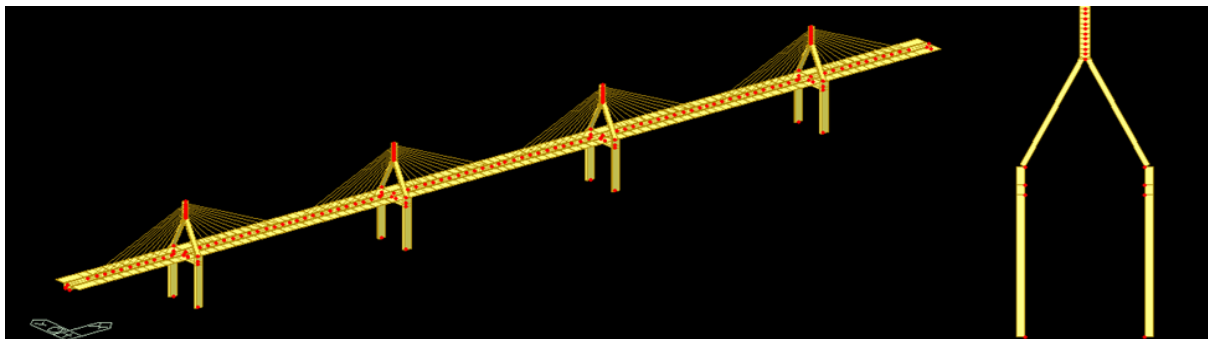
The pylons of same mass are modelled with two variations such as keeping same longitudinal and transverse dimension of pylon.



**Fig 2:** Layout of cable stayed bridge with Single pylon



**Fig 3:** Layout of cable stayed bridge with A type pylon

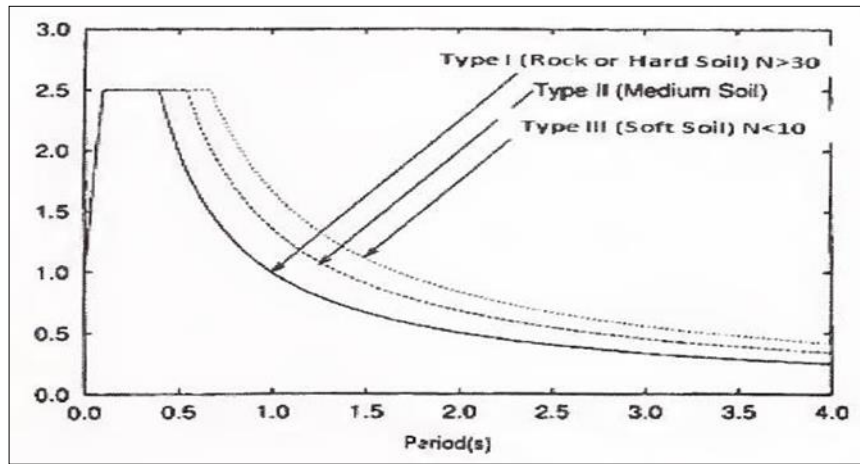


**Fig 4:** Layout of cable stayed bridge with Inverted Y type Pylon

**4. Analysis Methodology**

Elastic Response Spectrum Method is used for seismic analysis of cable stayed bridge. This is a general method, suitable for more complex structural systems (e. g. continuous bridges, bridges with large difference in pier heights, bridges which are curved in plan, etc), in which

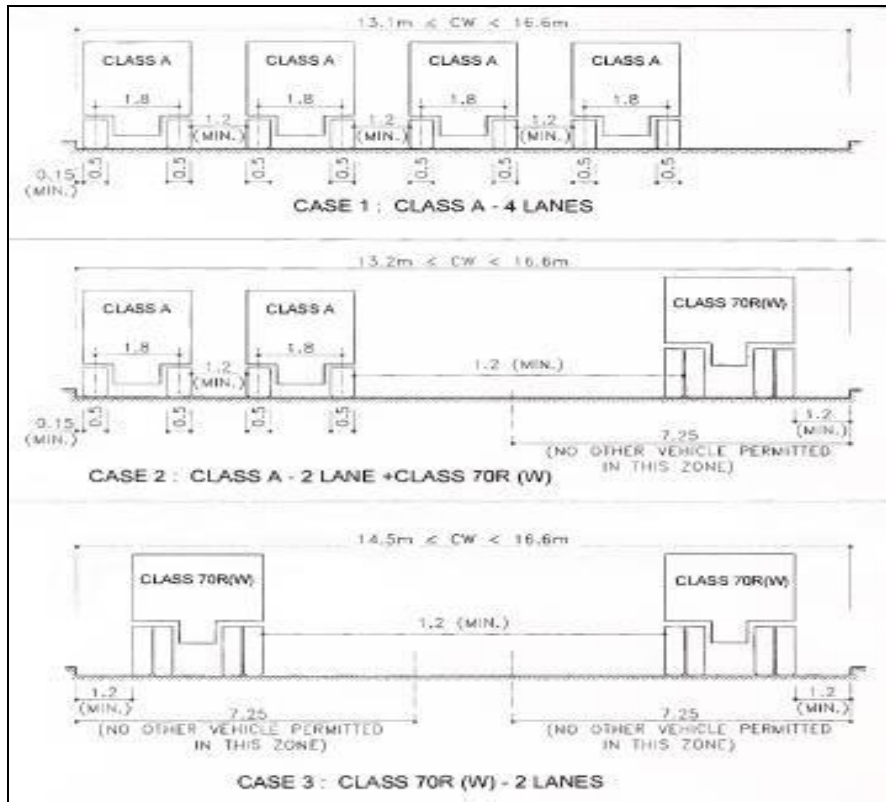
dynamic analysis of the structure is performed to obtain the first as well as higher modes of vibration and the forces obtained for each mode by use of response spectrum from Fig. 4:1 and Clause 219.5.1 from IRC 6. These modal forces are combined by following appropriate combinational rules to arrive at the design forces



**Fig 5:** Response spectra

In a present study, numbers of lanes are 4. For these lanes, 3 live load cases are described in cl. No. 204.3, Table no. 2, IRC 6: 2014. They are :- 1) Case I: Class A - 4 Lanes. 2)

Case II: Class A - 2 Lanes + Class 70R (W). 3) Case III: Class 70R (W) – 2 Lanes.



**Fig 6:** IRC Live Load Combination for 4 lanes

**5. Results and Observations**

In this paper, different key parameters of cable stayed bridge

are studied to get their influence on the principal characteristics of the target bridge, which are: height of the

pylon to the middle span ration; effect of shape and height of pylon on cable forces developed in cable of end span,

maximum deck and pylon deformation and base shear.

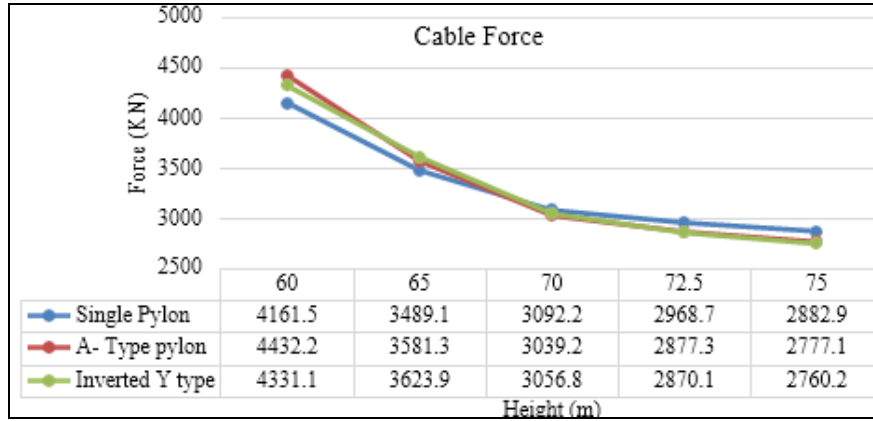


Fig 7: Cable forces in top most cable of end span for same longitudinal dim. of pylon

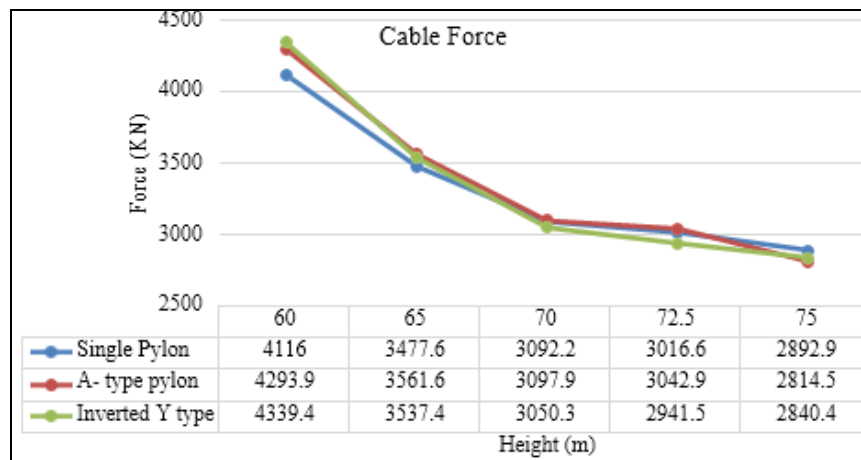


Fig 8: Cable forces in top most cable of end span for same transverse dim. of pylon

The Variation in cable forces with respect to height of pylon, for Single pylon is less as compared to A-type and Inverted Y type pylon having constant cross-sectional area and mass of pylon. The forces developed in cables of Single pylon, A-type pylon and Inverted Y type pylon are nearly same, for ratio of Span to Height of pylon above deck level, equal to

4.28. The force developed in cables for Single pylon are less as compared to A and Inverted Y type pylon for height of pylon less than 70 m whereas the forces developed in Single pylon are more as compared to A and Inverted Y type pylon for height of pylon more than 70 m as observed in Fig 7 and 8.

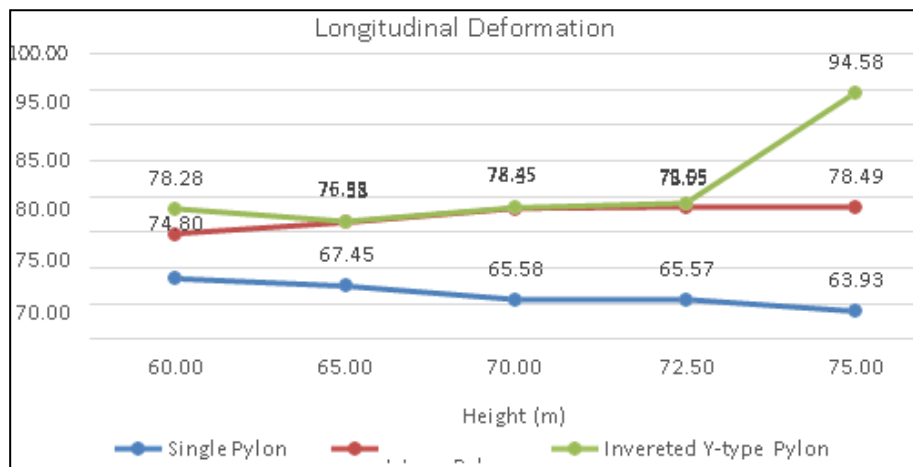


Fig 9: Pylon deformation in longitudinal direction for same longitudinal dim. of pylon

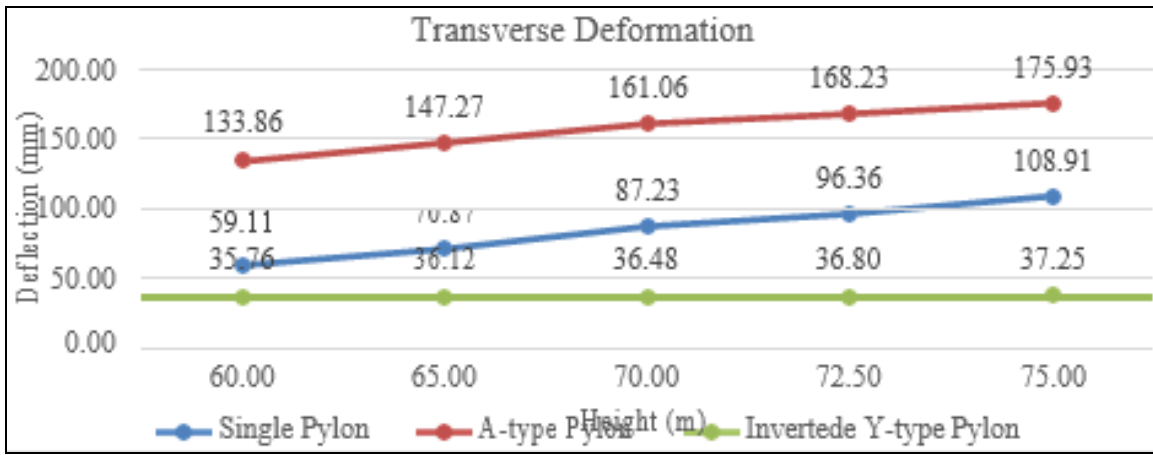


Fig 10: Pylon deformation in transverse direction for same longitudinal dim. of pylon

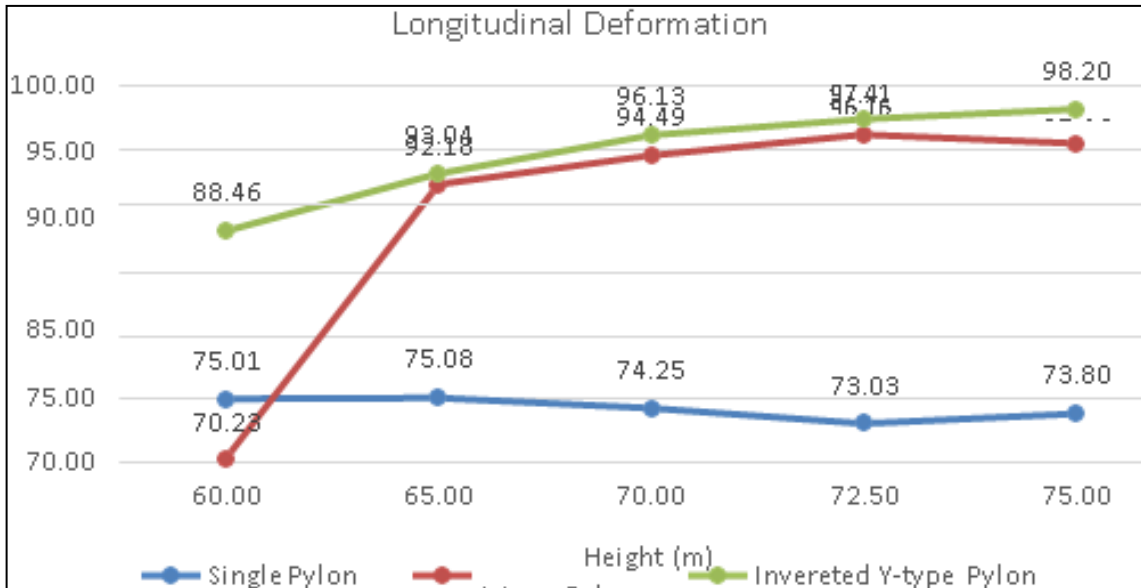


Fig 11: Pylon deformation in longitudinal direction for same transverse dim. of pylon

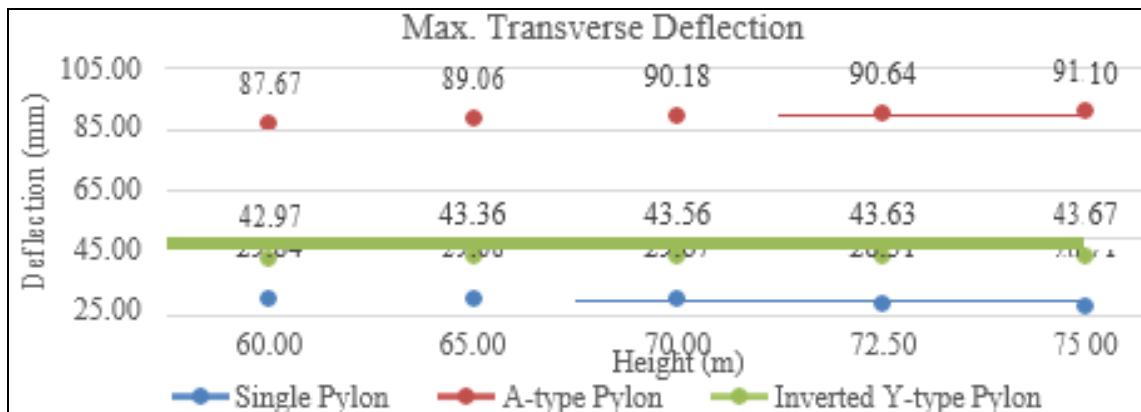


Fig 12: Pylon deformation in transverse direction for same transverse dim. of pylon

Pylon deformation in longitudinal direction for Single pylon is much less compared to other two types of pylons as observed in Fig 9 to 12. Pylon deformation in Transverse direction for Inverted Y type pylon is much less compared to

other two types of pylons as observed in figure 10 & 12. Pylon deformation is increased with increase in height of pylon for constant mass of pylon as observed in Fig 9 to 12.

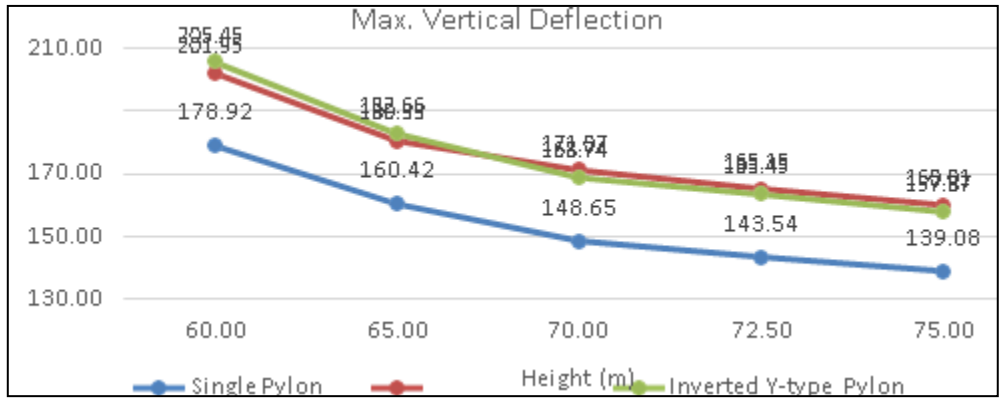


Fig 13: Max. Deck deformation in vertical direction for same longitudinal dim. Of pylon

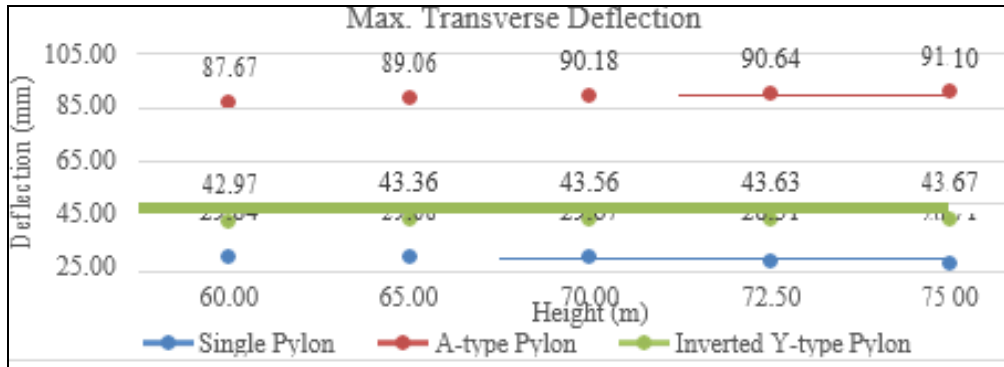


Fig 14: Max. Deck deformation in transverse direction for same longitudinal dim. of pylon

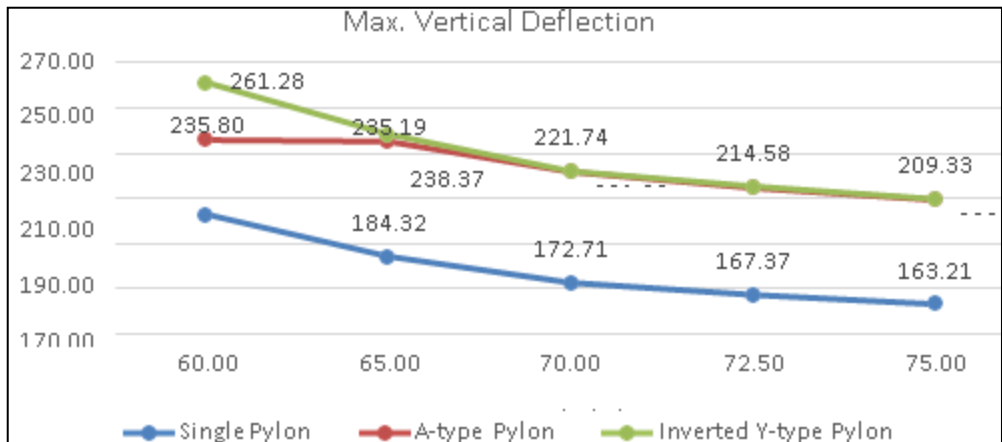


Fig 15: Max. Deck deformation in vertical direction for same transverse dim. of pylon

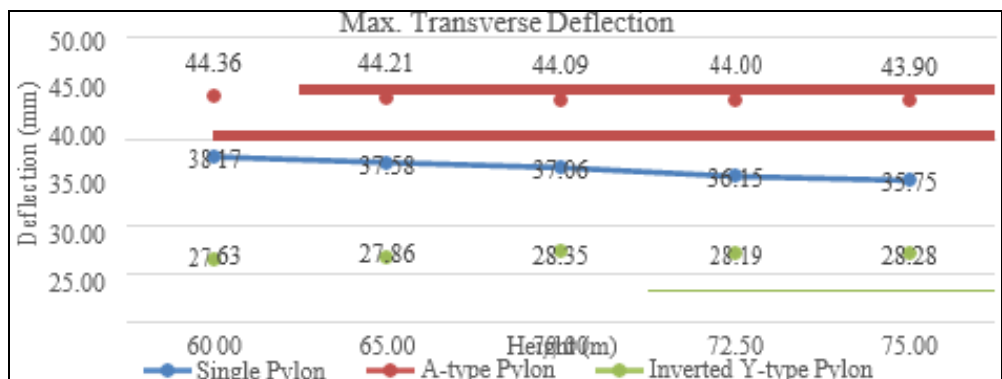


Fig 16: Max. Deck deformation in transverse direction for same transverse dim. of pylon

Maximum Deck deformation in vertical direction for single pylon is much less compared other types of pylon as observed in Fig 13 to 16. Maximum Deck deformation in transverse direction for Single and Inverted Y type pylon is much less compared other types of pylon as observed in

figure 14 & 16. The deck deformation is inversely proportional to height of pylon, i.e. the height of pylon increases, the deck deformation decreases as observed in Fig 13 to 16.

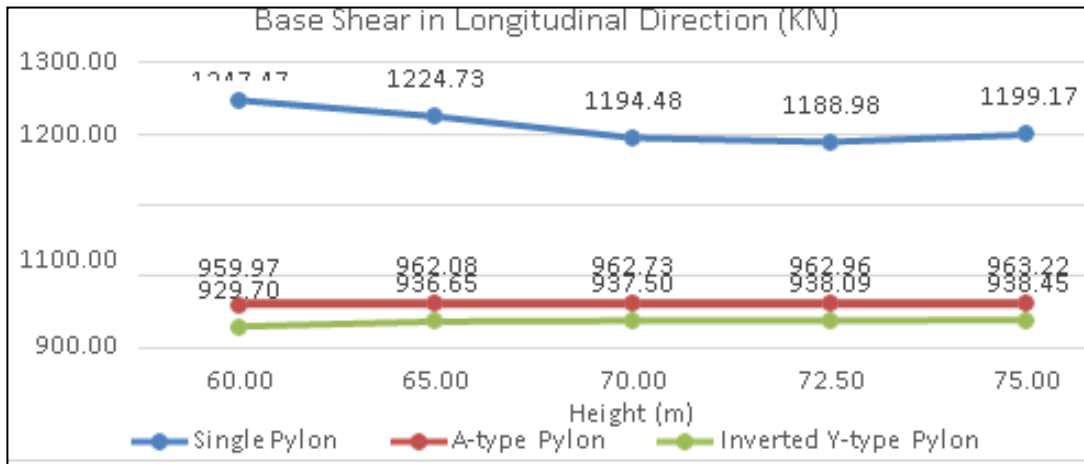


Fig 17: Base shear in longitudinal direction for same longitudinal dim. of pylon

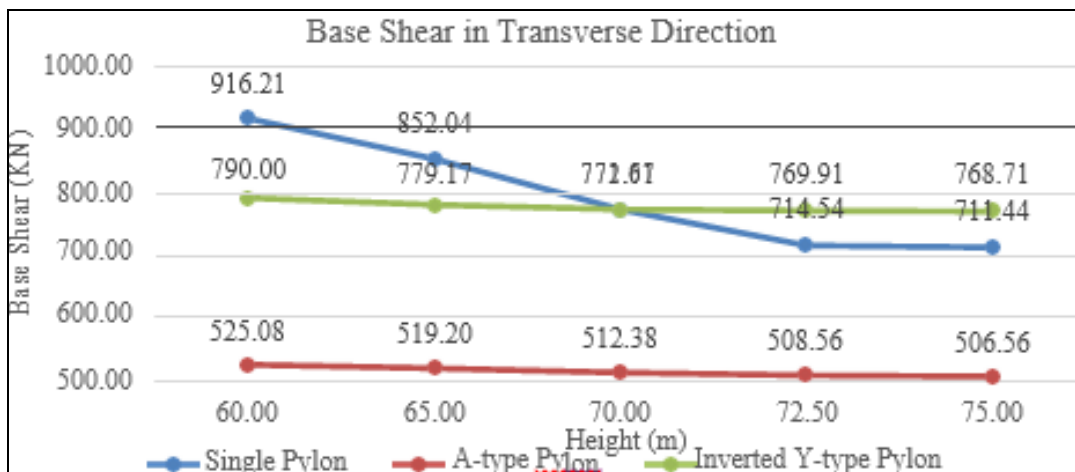


Fig 18: Base shear in transverse direction for same longitudinal dim. of pylon

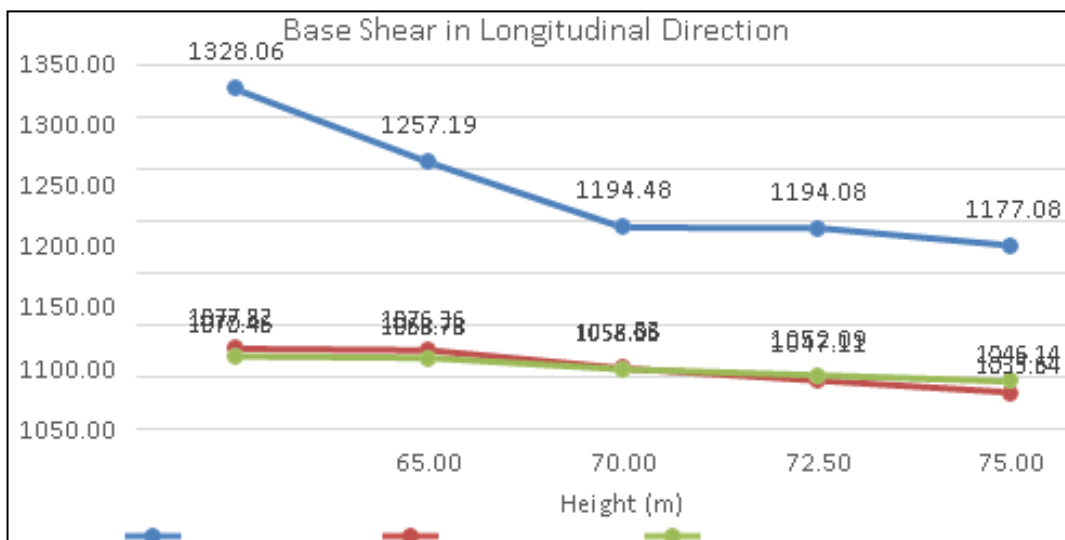


Fig 19: Base shear in longitudinal direction for same transverse dim. of pylon

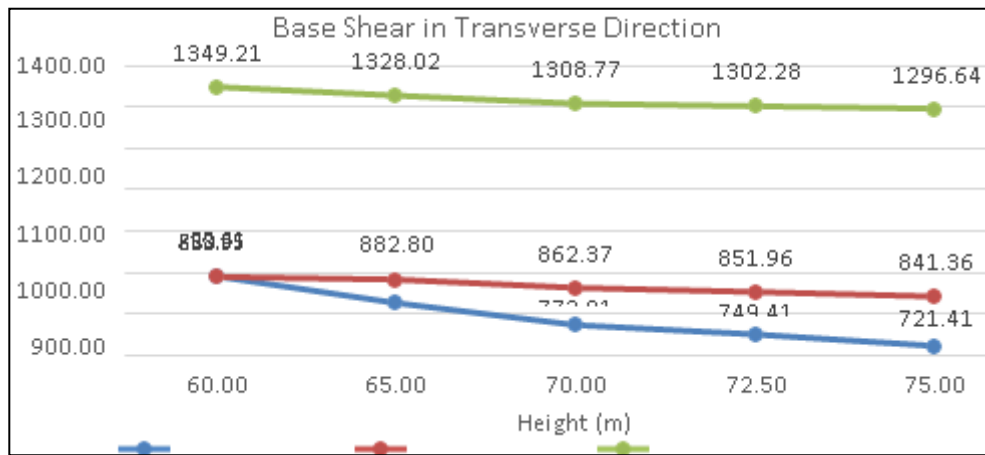


Fig 20: Base shear in transverse direction for same transverse dim. of pylon

Base shear in longitudinal direction for Inverted Y type pylon is much less as compared to other types of pylon of same longitudinal Dimension of pylon as observed in figure 17. Base shear in Transverse direction for A-type pylon is much less as compared to other types of pylon of same longitudinal Dimension of pylon as observed in figure 18. Base shear in longitudinal direction for A-type and Inverted Y type pylon is near to each other and attracts less base shear as compared to Single pylon of same transverse Dimension of pylon as observed in figure 19. Base shear in Transverse direction for Single and A-type pylon are nearly same and attracts less base shear as compared to Inverted Y type pylon of same transverse Dimension of pylon as observed in figure 20.

## 6. Conclusions

In this present study, the linear dynamic analysis is carried out considering the different types of pylons such as Single pylon, A type pylon and Inverted Y type pylon with the variation of heights, resulting in forces developed in cables, pylon and deck deformation and base shear of the structure. Therefore, for this present study it can be conclude that,

1. The increase in height of pylon decreases the tensile force in the cables. This is because, as the angle of inclination of cable with deck increases, the component of cables in vertical direction increases to carry the vertical load.
2. The single pylon has less deformation in longitudinal direction while Inverted Y type pylon has less deformation in transverse direction.
3. The single pylon has less deck deformation in vertical direction while Inverted Y type pylon has less deck deformation in transverse direction.
4. The Inverted Y and A type pylon have less base shear in longitudinal direction while A type pylon have less base shear in transverse direction.
5. Single pylon and Inverted Y type pylons are better than A type pylon from the parameters considered in this study.
6. Thus, from the all above conclusions, it is seen that, there is no uniformity in the response of different shapes

of pylons under different conditions. So, it cannot be merely concluded that, which of the pylons is better. Hence a detailed cost comparison (which includes method of analysis, cost of materials, constructions method, construction equipment's, time required for construction, site conditions, etc.) can only decide about the suitability of pylon.

## 7. References

1. Simon Niyitegeka. Influence of Cable Layout on the Seismic Response of Cable-Stayed Bridges, International Journal for Scientific Research & Development. 2015; 3:560-566.
2. Gian Michele Calvi, *et al.* Seismic Design of Cable-Stayed Bridges, 15th World Conference on Earthquake Engineering. 2012, 1-12.
3. Carlos Miguel Cabeçadas Calado. Structural Design of Cable-Stayed Bridges, Instituto Superior Técnico - Universidade Técnica de Lisboa. 2011, 1-9.
4. Yan XU, Shide HU. Seismic design of high-rise towers for cable-stayed bridges under strong earthquakes, Front. Archit. Civ. Eng. China. 2011; 5(4):451-457.
5. Tao Zhang, ZhiMin Wu. Dead Load Analysis of Cable-Stayed Bridge, International Conference on Intelligent Building and Management. 2011; 5:270-274.
6. Calvi GM, Sullivan TJ, Villani A. Conceptual Seismic Design of Cable-Stayed Bridges, Journal of Earthquake Engineering. 2010; 14:1139-1171.
7. Yasuyuki Suzuki, Hisanori Otsuka, Atsuo Otsuka. Seismic Analysis of Cable-Stayed Bridge with 2- Edge Girders, 13th World Conference on Earthquake Engineering. 2004; 1302:1-12.
8. HU Shide, YE Aijun. Seismic Conceptual Design of Long-Span Cable-Stayed Bridge, 12th World Conference on Earthquake Engineering. 2000; 2123:1-7
9. Wang PH, Tseng TC, YANG CG. Initial Shape of Cable-Stayed Bridges, Computers and Structures. 1993; 46:1095-1106.