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Seismic analysis of cable stayed bridge with different pylon shapes

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Abstract*— Cable stayed bridge are the most flexible bridge then other bridges and getting popularity because it represent optimum solution for ever expanding range of span and aesthetics . This work focused on the effect of shape of pylon on the transverse seismic response of cable stayed bridge for that the dimension of deck and other parameters are kept constant only the shape of the tower is varied, such as H-shape, inverted Y shape, inverted Y shape with lower diamond, A shape, A shape with lower diamond. This work also gives the essential information of the fundamental vibration mode which is based on mechanical and geometrical property of the structure. Which is required in early stage of design until optimum solution is not made. Five tower shapes of the lateral cable-system layouts are to be considered. The 3D model of the cable stayed bridge is generated in SAP-2000(VER.18) and it is analyzed seismically Bhuj 2001, Earthquake India. The response of bridge is studied in the terms of natural time period, displacement in transverse direction of pylon along the height, base reaction. This study reveals that the shape of the pylon play an important role in seismic response of cable stayed bridge. Inverted Y shape pylon is better in resisting when earth quake strikes from transverse direction.

***Keywords*— pylon shape, time history analysis, fundamental time period, displacement, base reaction**

1. INTRODUCTION

Cable stayed bridge is more flexible than other road way bridges due to their cable system arrangement, flexible deck, large height of pylon. So when the earthquake strikes on this type of flexible structure cause serious damage . Bridges are critical lifeline facilities which should remain functional without damage after an earthquake to facilitate the rescue and relief operations[1]. So when the design of cable stayed bridge is carried out it is necessary to give attention on seismic demand. The cable stayed bridge is more suitable then suspension bridges because in cable stayed bridge cable is directly connected to deck which provide greater stiffness. The mechanism of cable stayed bridge is very simple, cables carry deck load to the pylon and then foundation, in that case primary forces in structure are axial tension in cable and compressive forces in pylon. So the cables and pylon play an important role in transferring the load of super structure to foundation. So it is important to study of behaviour different pylon shape of cable stayed bridge. When the earthquake strikes on structure it has three components namely vertical and two lateral components which is longitudinal along the length of deck and transverse component which is along the width of the deck. The current trend in the design of cable-stayed bridges in seismic areas is to release the deck from the towers as much as possible in order to reduce the seismic demand in the towers, which are key elements for the integrity of the structure . However, the deck needs to be fixed to the towers in the transverse direction in order to control its deformability under wind actions (e.g. Rion-Antirion bridge, Greece). Recent studies on cable-stayed bridges with this type of connection have found that the deck–tower reaction significantly increases the transverse shear force and bending moment in the towers, making the transverse component of the earthquake more demanding than the longitudinal (along-deck) and vertical directions[2]. Several author's going through base isolation, dampers for reduced base reaction of cable stayed bridge [3], [4], but before going through it is necessary to check geometric advantages specially of different pylon shapes.

2. Description of the proposed bridges

The bridges considered in this work have300m main span length and 25m width of, deck have a 6 traffic lane, have a conventional symmetric configuration in x and y direction with a composite (steel–concrete) girder and two concrete towers. Fig.1 represents the different tower shapes proposed, the elevation and plan views, and the keywords employed to refer to the results in the following sections. The cross-sections of the tower, girder and cable-system are defined in terms of the main span length (LP), which also configures the side spans (LS) and the tower height above the deck (H). A complete description of the bridge sections and dimensions is available in [5]. There is no any intermediate side span support and deck is rigidly connected with pylon in transverse direction, free in longitudinally and vertically. In this study all models have lateral cable plane. In this study all the models of cable stayed bridge have fixed support at pylon bottom no soil structure interaction effect was considered.

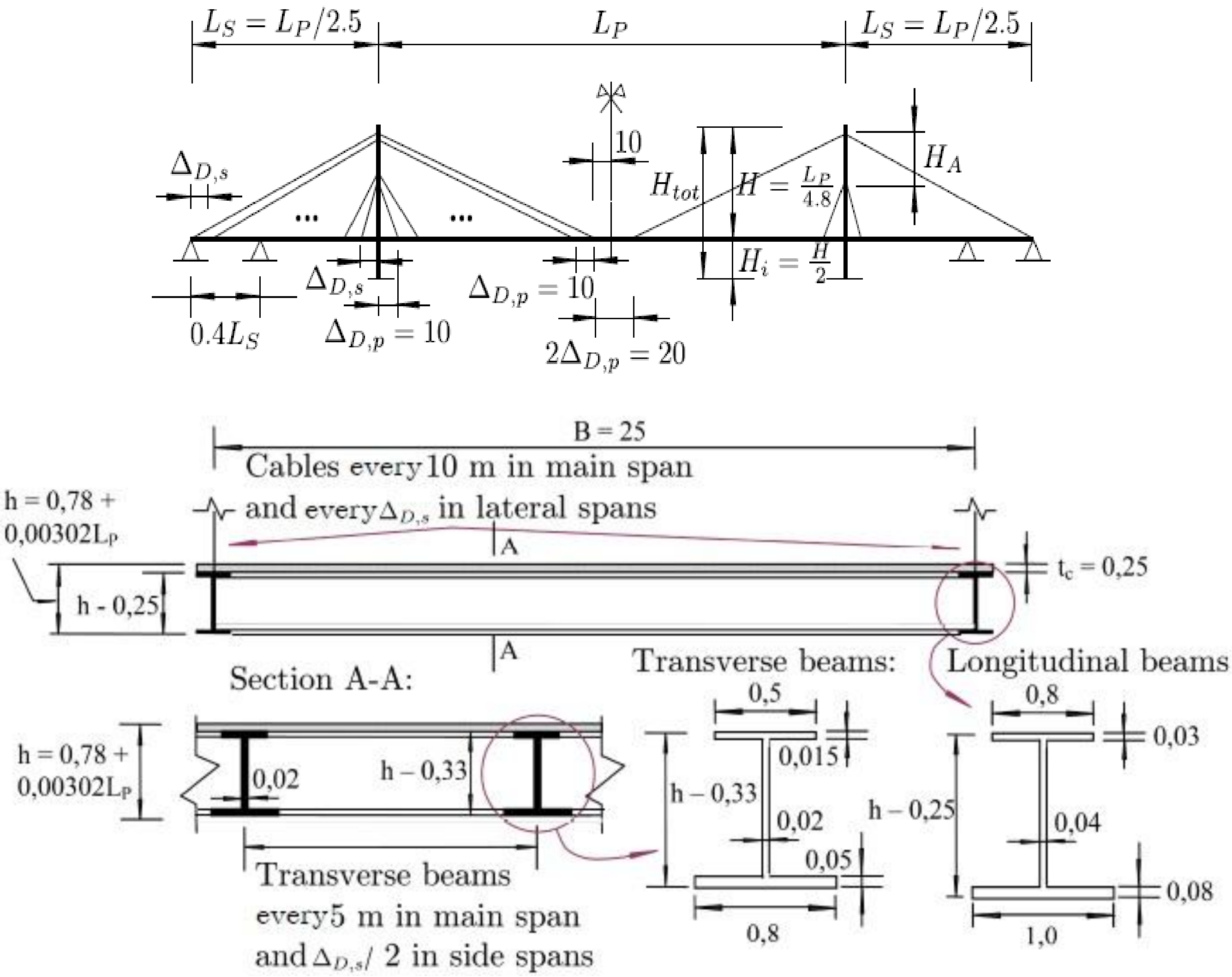

Fig1. Schematic bridge elevation and plan with the support conditions, in addition to the composite deck cross sections employed in lateral (LCP) cable plane configuration. Measurement in meter

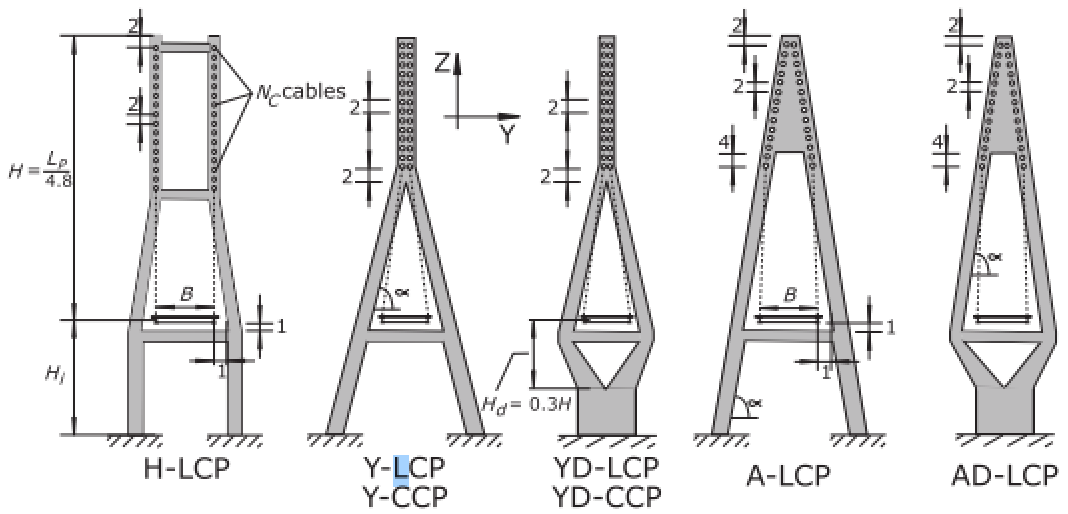

Fig.2. shapes of pylon

Common parameters of the cable stayed bridge having 300m and main span length

- material property

Table.1. Material property

	M50	**Fe 250**	**A416Gr270**
Material type	concrete	Steel	Prestressing cable
Minimum yield stress ($N/mm^{2)}$	50	250	1689.9052
Modulus of elasticity(N/mm^2)	27386.128	210000	196500.6
Use in	Deck slab and pylon	Longitudinal and transverse girder	cables

- Main span length (L_P) = 300M
- side span length (L_S) = L_P/2.5 = 120M
- Height of the tower above the deck level (H)=(L_P/4.8) = 62.5M
- Deck level (H_i) = H/2 = 31.25M
- Length of anchorage area in the tower = $H_A = \delta_T (N_T - 1)$ = 26M
  Where, δ_T = 2m and N_T = (Lp-20)/20 = 14M
- Configuration of Deck Section

  In all models of cable stayed bridge the cross section of deck remain same.

The deck holds six lane traffic lanes with steel concrete composite section. Which is commonly used to cover all the considered main spans and side spans. The axis of deck is horizontal and straight both in plan and elevation. The total width (B) is constant and equal to 25 m.

The depth of the deck (h) = 0.78 + 0:00302L_P = 1.686m
Thickness of concrete deck slab = 0.250m

➢ Cross section of longitudinal and transverse girder

Table.2.diamension of longitudinal and transverse girder

Component	Longitudinal girder	Transverse girder
Outside height (m)	1.43	1.356
Top flange width (m)	0.8	0.5
Top flange thickness (m)	0.05	0.015
Web thickness (m)	0.04	0.02
Bottom flange width (m)	1	0.8
Bottom flange thickness (m)	0.08	0.05
Cross section area (m)	0.157	0.0733

Transverse girder is provided every 5m in main span and every 120/28 = 4.28m in side span.

- Design of cables

  Cables are provided as a lateral cable planes (LCP) in every models of 300m main span length. Spacing of cables is 10m in main span and 8.57m in lateral span. In initial stage , the area of cross section in each cable is obtain so that the vertical component of cable force balance the self – weight and the live load over the corresponding deck length , being their stress equal to **40%** of the ultimate stress in the prestressing steel of cable.

Since the allowable stress of stay is limited to 40% of its yield stress

Only for the design of the cables the combination of loads such as irc class A and irc class 70R were considered. And the self-weight of deck, longitudinal girder, and transverse girder are taken as dead load. According to dead load and live load and panel length, and angle of cable with horizontal deck the reaction at each cable point was calculated.

Area of cable = R/{(0.4*1689)*sin(α)}

Where R = reaction at point of cable joining at deck due to dead load and live load.

α = angle made by cable with horizontal deck.

For example calculate area of cable and tensile force transfer in the cable no 14 of main span

- Reaction due to dead load

  total dead load form the deck slab = (6.25+1.76+0.64) = 8.65 kN/m^2(weight of slab ,footpaths, Krebs, W.C)

  Therefor 8.65*12.5*15 = 1621.87KN (where, 12.5 =half width of deck & 15= panel length for last cable)

  Dead weight of longitudinal girder = 12.084*15 =181.26 KN

  Dead weight of transverse girder = 5.64 * 37.5 = 211.5 KN

  Total dead load reaction = (1621.87 + 181.26 + 211.5) =**2014.63 KN**

- Reaction due to live load

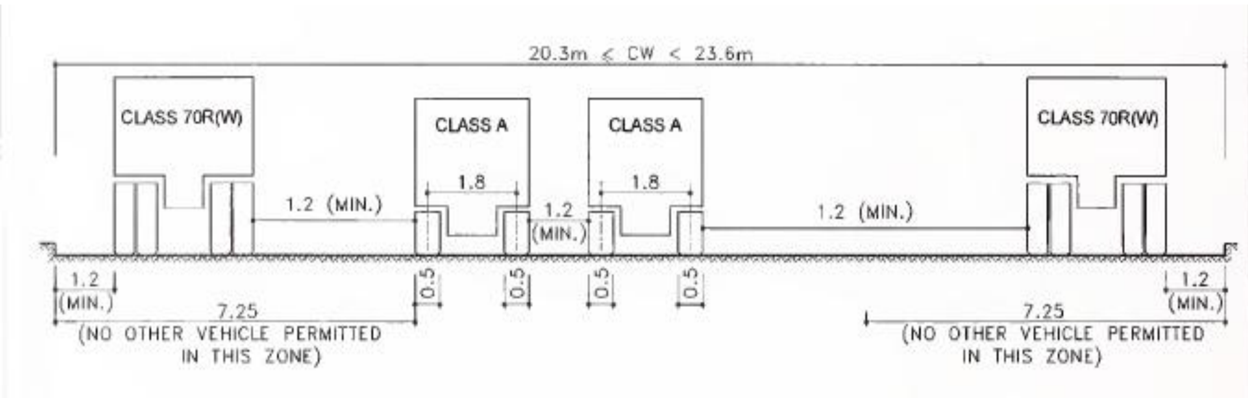

Fig.3. combination of classs A and class 70R loading

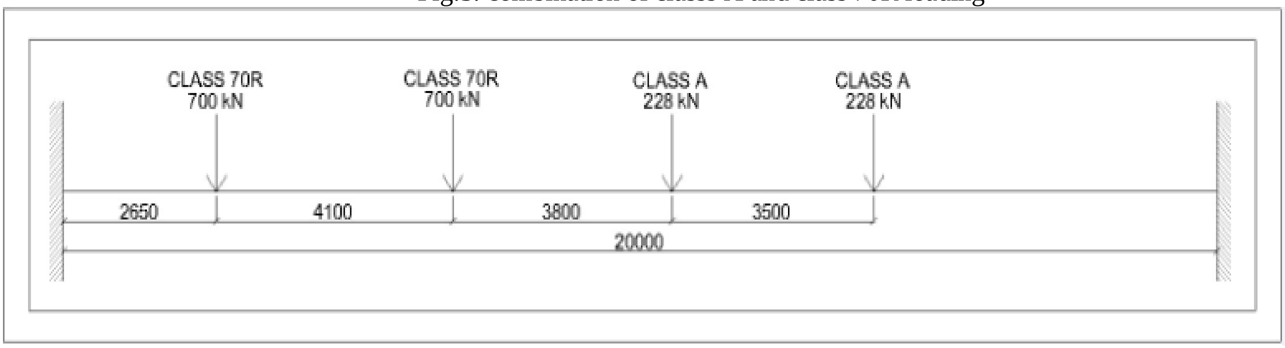

Fig.4.maximum live load reaction position

Taken 10% For impact

=1.1***[**{(700*17.35)/(20)+(700*13.25)/(20)+(228/9.45)/(20)+(228*5.95)/(20)}] = 1246.56KN

Total reaction R =2014.63 + 1246.56 **= 3261.19 KN**

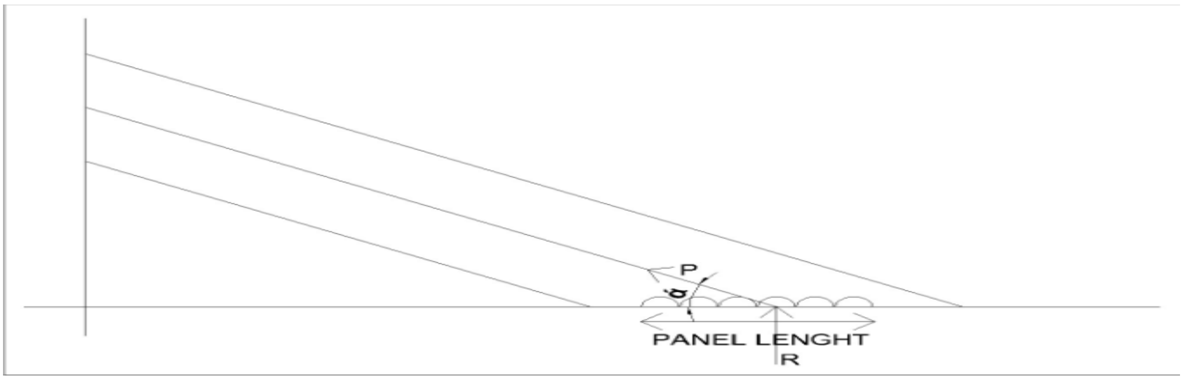

Fig.5. computation of force in cable

Angle of last cable with horizontal = **α =**$\tan^{-1}$(60.5/140) =23.37 deg

- Therefor area of last cable = R/{(675.6)*sin(α)} = 12180.92 mm^2

- Therefor diameter = 124.56mm

Table.3.diameter of cables of main and side span

Main span				side span		
Cable no	Cable Angle	Reaction (N)	Dia(mm)	Cable Angle	Reaction (N)	Dia(mm)
14	23.37	3262000	124.5676586	26.75	1867000	88.56334
13	24.22	2579000	108.9135107	27.07	2418000	100.235
12	25.21	2579000	106.8877334	28.78	2418000	97.44989
11	26.35	2579000	104.7080062	30.03	2418000	95.58043
10	27.69	2579000	102.3335149	31.48	2418000	93.56766
9	29.29	2579000	99.73329353	33.2	2418000	91.37337
8	31.22	2579000	96.89323592	35.27	2418000	88.97684
7	33.59	2579000	93.78488933	37.77	2418000	86.38993
6	36.56	2579000	90.38318161	40.86	2418000	83.58662
5	40.36	2579000	86.68296287	44.75	2418000	80.57147
4	45.35	2579000	82.7017125	49.74	2418000	77.38218
3	52.073	2579000	78.53826196	62.06	2418000	71.90229
2	61.27	2579000	74.48509264	69.75	2418000	69.75933
1	73.83	3262000	80.03670446	79.08	2989000	75.79313

Table.4.Diamension of pylon

component	Width (m)					Depth(m)				
	H	Y	YD	A	AD	H	Y	YD	A	AD
Top portion of pylon	2.5	4.80	4.80	4.80	4.80	4.16	3.47	3.47	3.47	3.47
Mid portion of pylon	3.125	2.717	2.717	2.717	2.717	4.16	3.47	3.47	3.47	3.47
Bottom portion of pylon	4.8	3.125	3.125	2.717	2.717	4.8	3.47	3.47	3.47	3.47
Top bracing	2.5	-	-	-	-	2.6	-	-	-	-
Mid bracing	3.28	-	-	-	-	3.47	-	-	-	-
Bottom bracing	3.47	3.47		-	-	2.71	2.71	-	-	-
Bottom	-	-	10.41	-	10.41	-	-	4.16		4.16

3. Model analysis

For dynamic analysis structure nonlinear model time history method is used.in this study time history of bhuj earthquake is selected.

Table.5. Details of earthquakes considered in this study

Earthquake	recording station	transverse direction Component	total time
Bhuj 2001	Ahemdabad	23 02 N	34.94 (sec)

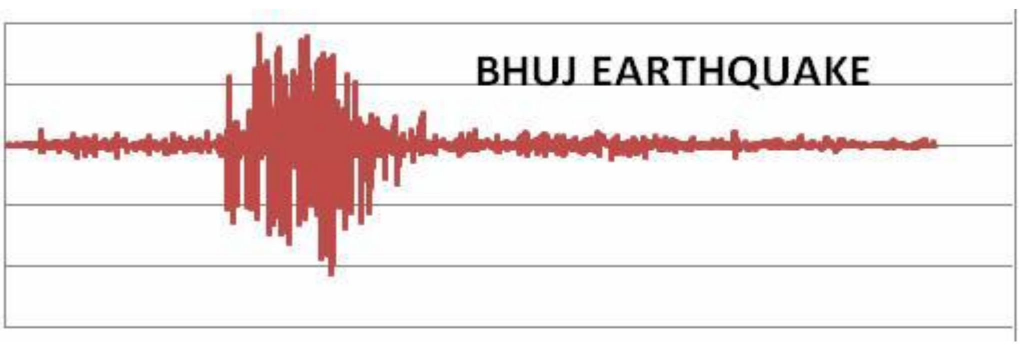

Fig.6. Bhuj earthquake time history

4. Results and discussion

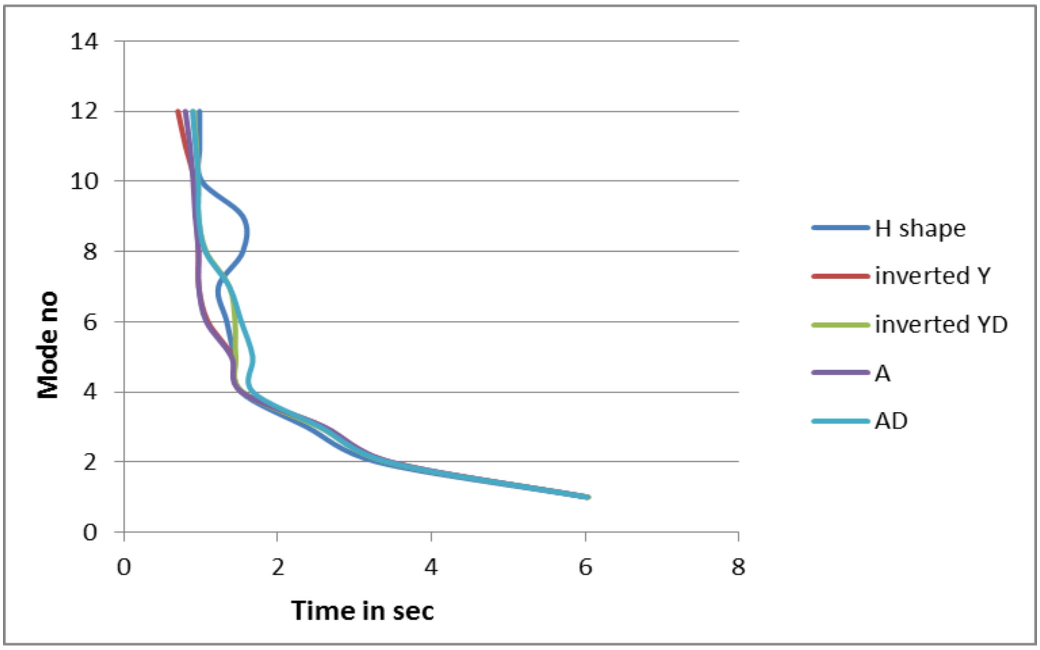

FIG.7. effect on natural time period for various shape of towers

Up to four modes there is no significant difference in natural time period for all shape, because all models have same heights and approximately same mass. After mode no 4 there is change in time period appear in all shape of pylon shape cable stayed bridge, because different geometries of the pylon. After mode no 4 the time period of h shape cable stayed bridge is relatively large then others.

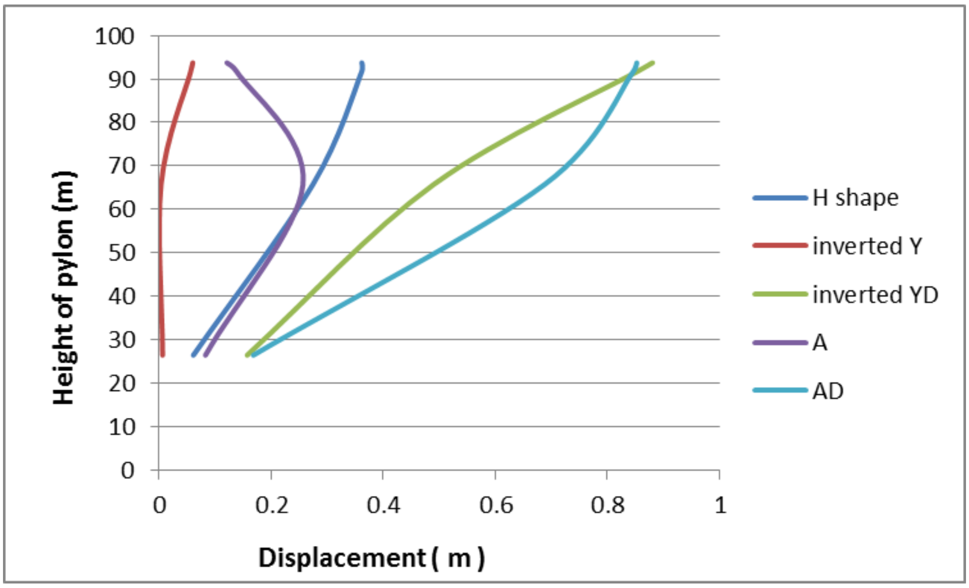

Fig.8. displacement of different shapes of pylons with respect to height

This chart show displacement of pylon in transverse direction at different levels such as level bottom bracing , level at which cable start, level of cable ending and top of pylon. We can show that the displacement of inverted Y shape tower is very low with compare to other pylons. Which is because of transverse movement of the connection point above the deck is constrained in the transverse direction due to the inclination of the legs, on other hand in YD shape of pylon which show more displacement then Y shape because connection of legs below deck ,for better understanding we can resist more force in transverse direction when we stand with making distance between two legs in transverse direction then we stands with joining both legs. This effect is also can see in A shape and A shape with lower diamond shape pylon. Due to larger inclination angle in A shape pylons then Y shape pylons which result more displacement in transverse direction.

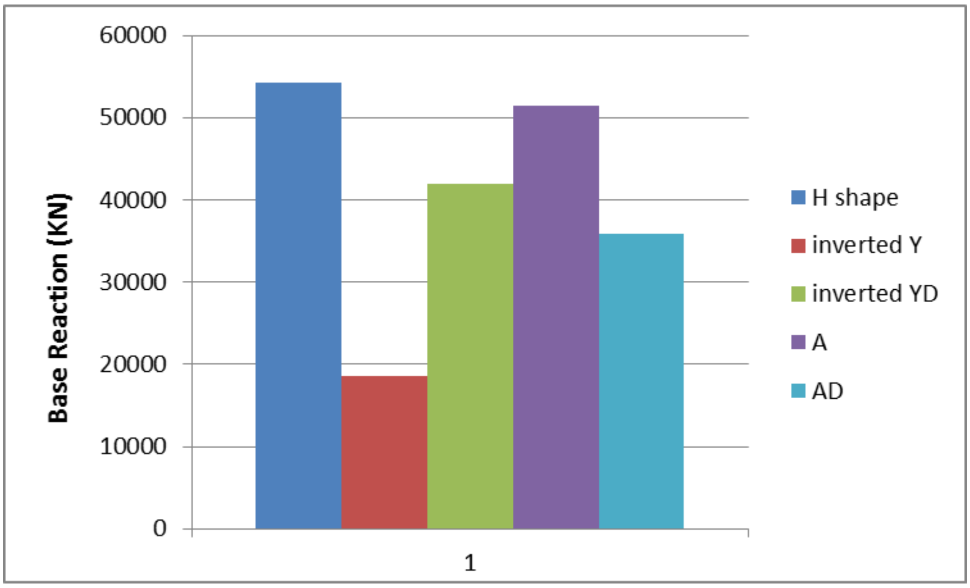

Fig.9. base reaction of cable stayed bridge with different shape of pylon

Base reaction of inverted Y shape without lower diamond cable stayed bridge is very low with compare to other.

5.Conclusions

In this study dynamic analysis of cable stayed bridge with 5 different pylon shapes were carried out in SAP2000 by time history method. It concludes that the shape of pylon plays an important role in transverse seismic response of cable stayed bridge.

1. after 4 mode the natural time period of H shape cable stayed bridge is relatively large then other shapes, so H shape pylon prove to be flexible then other. On other hand the natural time period of inverted Y and A shape pylon is less which show that which is relatively stiff.
2. Inclination of pylon legs above deck plays an importance role in transverse seismic response of cable stayed bridge.
3. After study the different parameters, the inverted Y shape without lower diamond prove to be ideal option when we considering seismic response of cable stayed bridge in transverse direction.

References

[1] S. G. Shah, B. Gujarat, and A. Mechanics, “Effect of Pylon Shape on seismic response of Cable stayed bridge with soil,” vol. 1, no. 3, pp. 667–682, 2010.

[2] A. Camara and E. Efthymiou, “Deck–tower interaction in the transverse seismic response of cable-stayed bridges and optimum configurations,” *Eng. Struct.*, vol. 124, pp. 494–506, 2016.

[3] B. B. Soneji and R. S. Jangid, “Passive hybrid systems for earthquake protection of cable-stayed bridge,” vol. 29, pp. 57–70, 2007.

[4] B. B. Soneji and R. S. Jangid, “Response of an isolated cable-stayed bridge under bi-directional seismic actions,” vol. 6, no. 3, pp. 347–363, 2010.

[5] a. Camara, M. a. Astiz, and a. J. Ye, “Fundamental Mode Estimation for Modern Cable-Stayed Bridges Considering the Tower Flexibility,” *J. Bridg. Eng.*, vol. 19, no. 6, p. 4014015, 2014.

[6] R. Congress, “AND CODE OF PRACTICE,” 2014.