Analysis of the behaviour of Cable stayed bridge with different types of Pylon

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Abstract. Cable stayed bridges are known for their good stability, It has been the most favorable use of structural design, for comparatively low designing and maintenance costs, and for effective structural characteristics. Therefore, this type of bridges are gaining popularity and are generally selected for long spans when compared to suspension bridges. A cable stayed bridge comprises of pylons with cables withstanding the weight of deck. There are different types of pylons i.e. ; H-type pylon, A-type pylon, inverted Y-type pylon, and diamond shaped pylon. In this paper the bridge design, model, and analyses for these different types of pylons is done using STAAD Pro. The comparison for three cases are done on the basis of shear force and bending moment in terms of self weight to obtain the most efficient type of pylon design. The results thus obtained are useful in limiting the drawbacks of other types of pylon.

1 Introduction

The cable stayed bridge was introduced at the time that of the suspension bridge, however due the initial collapse of the cable supported bridges constructed over the river Tweed and Saale, parts of Europe and Germany. Initially from 19th century, the concept was then starting to commence. A huge number of bridges that were destructed, because of the World War, it became essential to reconstruct them. With a shortage of steel at the precedence time, eequirements of new bridges were being issued. Construction was to be done with the least possible weight. The main vision during the construction was to provide economical material and level the construction with minimum cost ; hence engineers adopted the concept of the cable stayed bridge. The Stromsund Bridge (Sweden) in 1955 was the first modern cable stayed bridge [1]. Cable Stayed Bridges are famous for structures which requires large span in order to secure maintenance costs [2]. The important functions of such structures are the utilization of steel cables as axial force resistant members, suppose as due to their high strength. Mostly popular in for the cable supported bridges [3]. Cable stayed bridges, spring from the principle of cables processing as a tension resistance structural member when the load is transferred to pylon and then to the piles [4]. From 21st century, cable-stayed bridges have been gaining a name for itself globally. Construction with a total span of approximately 1 km. As compared to suspension

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bridges, the main factors are the attractive aesthetics, the shorter construction time, the effective use of materials for the building structure, the light appearance, and most significantly, the increased stiffness. Structures with these characteristics often have a long-life span, a high degree of stability, are light in weight, and have low structural damping [5].In this paper we shall discuss the analysis of different cable stayed bridges and their behavior based on different pylon. Specifically, H-type, A-type, Y-type.

2 Literature Review

The cable stayed bridges are more widely coming in practice due to the enhanced steadiness and the long range of bridges over the other different types of bridges. A cable stayed bridges is a type of bridge in which the load of the deck is sustained or balanced by the different cables those are running either parallel or are connected together specifically to at least one tower. It is mainly focused on the different types of pylons used in the cable stayed bridge, for example, single pylon, A type, H type, inverted Y type, diamond shaped, U-shaped, hexagonal in shape, etc. The height of the pylon is constant for different shapes of pylons for cable stayed bridge. The impact of these different shapes of pylons on the seismic reaction of the cable stayed bridge is illustrated in this study. Single pylon is grounded lengthwise in order to restrain earthquake drive whereas inverted Y type pylon is grounded sideways to oppose earthquake restrain [6-7].
The linear analysis of cable stayed bridges for different shapes of pylons under its self-weight. The conclusions regarding the axial force in pylon, bending moment in pylon, shear force in pylon and deflection at the top of pylon was given. The main aim of the study is to help in shape selection of the pylon for particular conditions for cable stayed bridge.The configuration for different pylons of the cable stayed bridge along with the vehicular movements was illustrated. He gave the finite element approach for geometric nonlinear aerostatic analyses of self-anchored cable stayed bridge. The construction of a cable stayed bridge achieving the desired strength and serviceability, meeting all the design criteria along with the minimum cost is a challenging task [8-9]
In the recent studies some studies gave a practical view on Static Analysis of Cable Stayed Bridges. The study discusses about how cable stayed bridges has helped designers to control and adjust the forces of different elements of bridges as when the load is fixed the beam forces can be changed by adjusting cable forces which allows designer to control beam forces of the bridge, these structures are also known as Active Structures [10-11].
The optimization of bridge design is very necessary to obtain a cost effective and sustainable bridge model. There are certain criteria to obtain optimized cable stayed bridge model. After obtaining the optimization of cable stayed bridges, analysis is run to observe the cable forces, bending moment of girder/span and design load before starting the construction of cable stayed bridge. There are two methods to optimize cable stayed bridge model, one of them is Stiff cable method and another one is unit load method. There is also a need to study non-linear behavior of cable stayed bridge, which basically results from non-linear geometrical design and material [12-14].

3 Analysis

3.1 Objective

- To evaluate current construction practices and assess the data of the project sites. Designing and modeling of a 3-d structure of cable stayed bridge and analysing their shear force behavior, bending moment and deflection.

- Assess information of the constructed cable stayed bridges by providing a detailed case studies for the bridges.
- Analyzing all the forces and stresses applied on the proposed model.
- Comparison of the most efficient pylon designs are obtained based on their shear force, bending moment and deflection.

3.2 Description of Bridge

In this analysis, the Cable Stayed Bridge is studied for the three types of pylons i.e. inverted Y-type, H-type, A-type. The comparison is made for the three types for shear force, bending moment and displacement. The analysis is done by using STAAD Pro software. The most efficient pylon type is proposed after comparison of the cable stayed bridge that follow the same parameters for the construction. The construction is carried out in three phases. Firstly, designing of deck, followed by that of pylon and later moving onto cable arrangement.

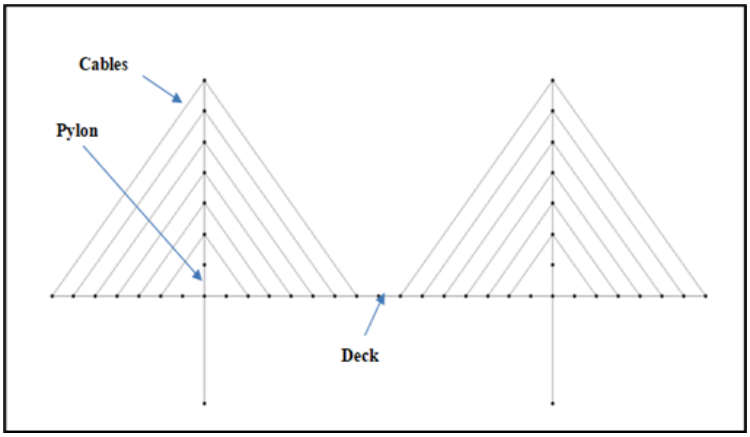

Fig. 1. Parts of Cable Stayed Bridge

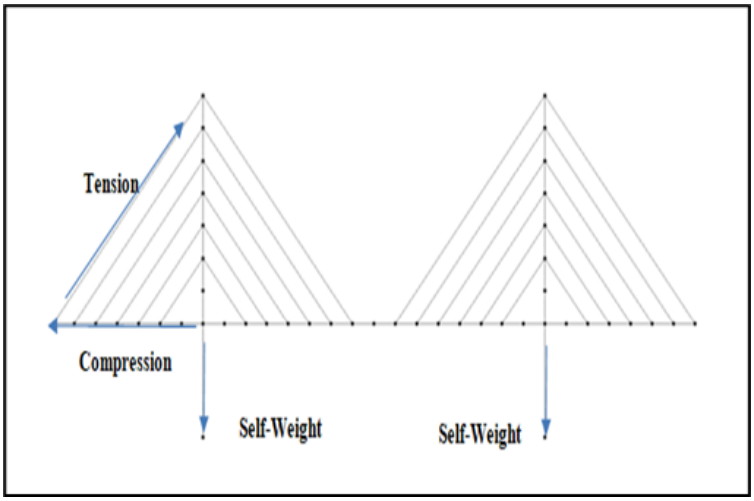

Fig. 2. Loads carried by the bridge

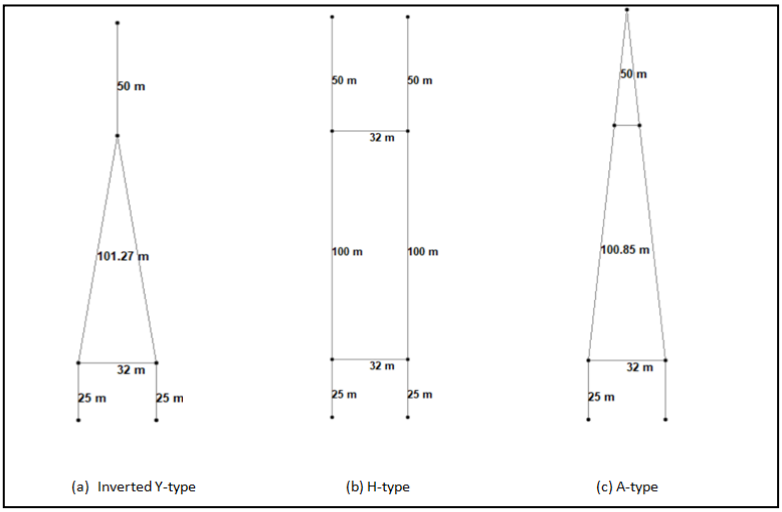

Fig. 3. Parameters of the Pylons

3.3 Model Information

Table 1. Design Configuration of Cable Stayed Bridges.

S. No.	Parameters	
1.	Type of stay cables	Parallel wires
2.	Longest span	100m
3.	Total Length	200m
4.	Height of Pylon	150m
5.	Clearance below Cable stayed and sea level	25m
6.	Type of cable arrangements	Harp type
7.	Total Number of Pylons	2
8.	Total Number of Cables	60
9.	Deck width	32m
10.	Number of Lanes	2

3.4 Model Designing

Designing a cable stayed bridge requires mainly structural parameters which are necessary for the design of the stability of the bridge. Designing mainly requires steps which would help in the construction of the bridge. The main steps for the design of a cable stayed bridge are determined by the steps given below:

- Determine the back span to the main span ratio. Determining the back span to main span ratio, the formula used is $a/b<0.5$.
- Determining the cable spacing. The cable spacing which is used should be minimum to use the cantilever method.
- Determine the deck stiffness. Minimum deck stiffness to carry large compressive forces without the action of buckling should be used.
- Determine the pylon height. A pylon height should be more above the deck and less below the deck with the width of the below pylon to be more than the pylon which is residing above the main deck.
- Determining the preliminary cable forces.
  Deck design formation. Deck erection (backward or forward stage analysis).

- Static analysis i.e., the dead load analysis.

Modelling of the cable stayed bridge for the self-weight analysis i.e., the dead load of the structure for the analysis of the deflection, shear force and bending of the cases are done. Staad Pro v8i has been used to analyze the load for the structures modelled. There has been a numerous finding and challenges that has been faced during the formation of these bridges. Mainly including about the parameters of the bridge. No such improvisations were necessary to make the structure more stable. Elastic Modulus error were faced mostly as the surface thickness provided for the bridges were not able to sustain from the cable's arrangements. However, by raising the grade of concrete pylon to M60, such problems were easily fixed.

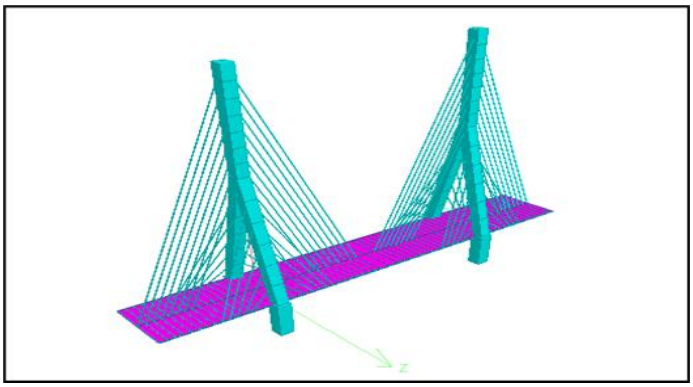

Fig. 4. Rendered Image of Inverted Y-Type Pylon

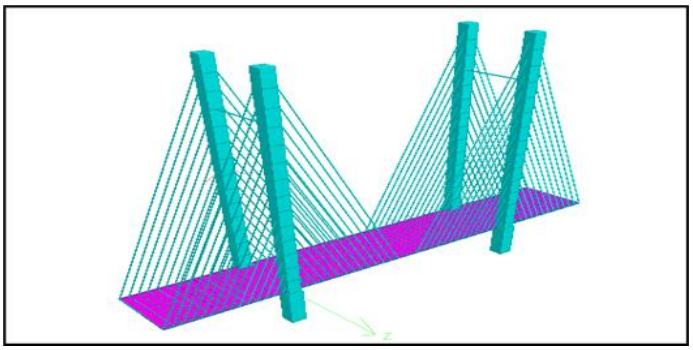

Fig. 5. Rendered Image of Inverted H-Type Pylon

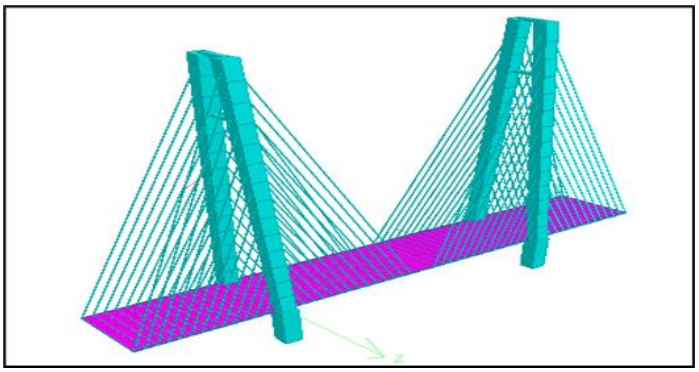

Fig. 6. Rendered Image of Inverted A-Type Pylon

Table 2. Material properties

S. No.	Name	E, (KN/mm2)	Density, (Kg/m3)
1.	FE500	500000	7.83E+3
2.	M60	60.000	2.4E+3
3.	STEEL	205	7.83+3
4.	STAINLESS STEEL	197.930	7.83+3
5.	ALUMINIUM	68.948	2.71E+3
6.	CONCRETE	27.718	2.4E+3

3.5 Comparison of Models

Table. 1. Beam End Displacement for Inverted-Y

	Beam	**Node**	**L/C**	**X** (mm)	**Y** (mm)	**Z** (mm)	**Resultant** (mm)
Max X	34	4	1:D.L	**183.154**	-22.324	0.000	184.510
Min X	292	206	1:D.L	**-190.140**	-22.448	0.000	191.461
Max Y	393	311	1:D.L	0.000	**0.000**	0.000	0.000
Min Y	198	135	1:D.L	-0.012	**-1.0E+4**	0.005	1.0E+4
Max Z	535	322	1:D.L	29.187	-17.323	**23.066**	41.037
Min Z	530	317	1:D.L	29.187	-17.323	**-23.066**	41.037
Max Rst	198	135	1:D.L	-0.012	-1.0E+4	0.005	**1.0E+4**

Table. 2. Beam End Force for Inverted-Y

	Beam	**Node**	**L/C**	**Shear Force (KN)**	**Shear Force (KN)**	**Bending Moment (kNm)**	**Bending Moment (kNm)**
				Fy (kN)	**Fz** (kN)	**My** (kNm)	**Mz** (kNm)
Max Fx	393	311	D.L	-1.11E+3	7.3E+3	7E+4	-2.99E+3
Min Fx	318	228	D.L	0.285	0.000	0.000	0.000
Max Fy	266	29	D.L	**7.25E+3**	-183.237	-4.99E+3	1E+5
Min Fy	543	245	D.L	**-6.95E+3**	416.425	3.1E+4	9.3E+4
Max Fz	395	245	D.L	1.11E+3	**7.54E+3**	-1E+5	3.1E+4
Min Fz	396	278	D.L	1.11E+3	**-7.54E+3**	1E+5	3.1E+4
Max Mx	543	329	D.L	-4.59E+3	416.425	2.5E+4	1.0E+4
Min Mx	548	334	D.L	-4.59E+3	-416.425	-2.5E+4	1.0E+4
Max My	394	169	D.L	-1.11E+3	-7.3E+3	**1E+5**	-3.1E+4
Min My	393	102	D.L	-1.11E+3	7.3E+3	**-1E+5**	-3.1E+4
Max Mz	266	29	D.L	7.25E+3	-183.237	-4.99E+3	**1E+5**
Min Mz	530	317	D.L	178.637	-271.298	-1.5E+4	**-5.4E+4**

Table. 3. Beam End Displacement for A type pylon

	Beam	**Node**	**L/C**	**X** (mm)	**Y** (mm)	**Z** (mm)	**Resultant** (mm)
Max X	61	62	D.L	**8.314**	-23.837	-0.071	25.246
Min X	238	152	D.L	**-8.310**	-23.837	-0.071	25.244
Max Y	4	5	D.L	0.000	**0.000**	0.000	0.000
Min Y	125	91	D.L	0.000	**-518.736**	-0.010	518.736
Max Z	113	85	D.L	2.635	-20.358	**39.060**	44.126
Min Z	100	72	D.L	2.635	-20.358	**-39.058**	44.124
Max Rst	125	91	D.L	0.000	-518.736	-0.010	**518.736**

Table. 4. Beam End Force for A type pylon

	Beam	Node	L/C	Shear Force (KN)	Shear Force (KN)	Bending Moment (kNm)	Bending Moment (kNm)
				Fy (kN)	Fz (kN)	My (kNm)	Mz (kNm)
Max Fx	4	5	D.L	-34.468	-4.68E+3	-3.8E+4	-525.673
Min Fx	61	62	D.L	424.120	0.000	3.022	497.224
Max Fy	109	80	D.L	**3.55E+3**	3.494	18.008	5.7E+4
Min Fy	295	93	D.L	**-3.85E+3**	-15.726	-1.35E+3	7.5E+4
Max Fz	241	123	D.L	34.468	**4.68E+3**	-8E+4	1.39E+3
Min Fz	182	93	D.L	34.468	**-4.68E+3**	8E+4	1.39E+3
Max Mx	4	1	D.L	-34.468	-4.68E+3	8E+4	-1.39E+3
Min Mx	65	32	D.L	-34.468	4.68E+3	-8E+4	-1.39E+3
Max My	182	93	D.L	34.468	-4.68E+3	**8E+4**	1.39E+3
Min My	241	123	D.L	34.468	4.68E+3	**-8E+4**	1.39E+3
Max Mz	295	93	D.L	-3.85E+3	-15.726	-1.35E+3	**7.5E+4**
Min Mz	113	85	D.L	185.003	11.102	415.146	**-4.3E+4**

Table. 5. Beam End Displacement for H type pylon

	Beam	Node	L/C	X (mm)	Y (mm)	Z (mm)	Resultant (mm)
Max X	61	61	D.L	**358.183**	-47.699	-0.146	361.345
Min X	236	151	D.L	**-358.180**	-47.699	-0.146	361.342
Max Y	17	3	D.L	9.640	**42.890**	-1.784	43.996
Min Y	146	89	D.L	0.000	**-252.623**	-0.599	252.624
Max Z	33	34	D.L	9.640	42.890	**1.783**	43.996
Min Z	193	93	D.L	-9.637	42.888	**-1.784**	43.993
Max Rst	61	61	D.L	358.183	-47.699	-0.146	**361.345**

Table. 6. Beam End Force for H type pylon

	Beam	Node	L/C	Shear Force (KN)	Shear Force (KN)	Bending Moment (kNm)	Bending Moment (kNm)
				Fy (kN)	Fz (kN)	My (kNm)	Mz (kNm)
Max Fx	4	5	D.L	-859.083	-263.516	-2.33E+3	-2.4E+4
Min Fx	323	94	D.L	-999.283	0.000	0.000	0.000
Max Fy	292	93	D.L	**999.283**	0.000	0.000	0.000
Min Fy	292	94	D.L	**-999.283**	0.000	0.000	0.000
Max Fz	237	122	D.L	859.083	**263.516**	-4.26E+3	4.5E+4
Min Fz	180	91	D.L	859.083	**-263.516**	4.26E+3	4.5E+4
Max Mx	4	1	D.L	-859.083	-263.516	4.26E+3	-4.5E+4
Min Mx	62	32	D.L	-859.083	263.516	-4.26E+3	-4.5E+4
Max My	4	1	D.L	-859.083	-263.516	**4.26E+3**	-4.5E+4
Min My	62	32	D.L	-859.083	263.516	**-4.26E+3**	-4.5E+4
Max Mz	180	91	D.L	859.083	-263.516	4.26E+3	**4.5E+4**
Min Mz	4	1	D.L	-859.083	-263.516	4.26E+3	**-4.5E+4**

4 Results and Discussion

In this section, the results for the efficient design of different pylons of cable-stayed bridges including H-type, A-type and inverted Y-type are presented. The purpose of this is to study the effect of different types of pylons on bridge component like cables, deck, and total cost. The graphical summarized results are as follows:

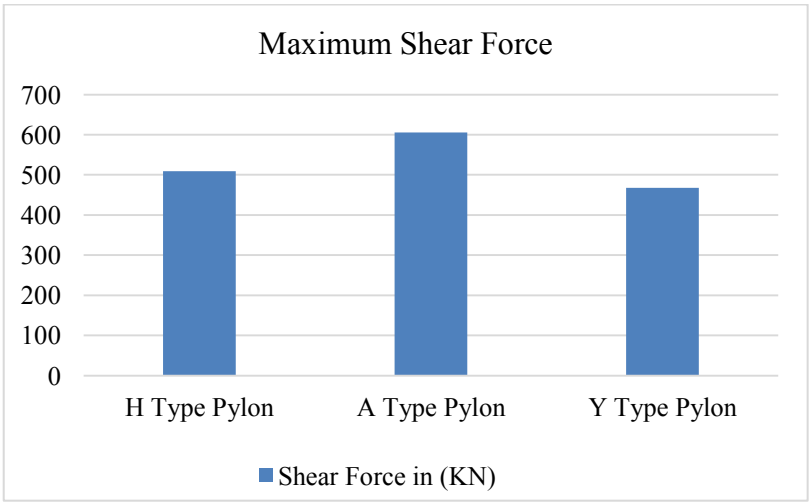

Fig. 7. Shear Force comparison for different type of pylons

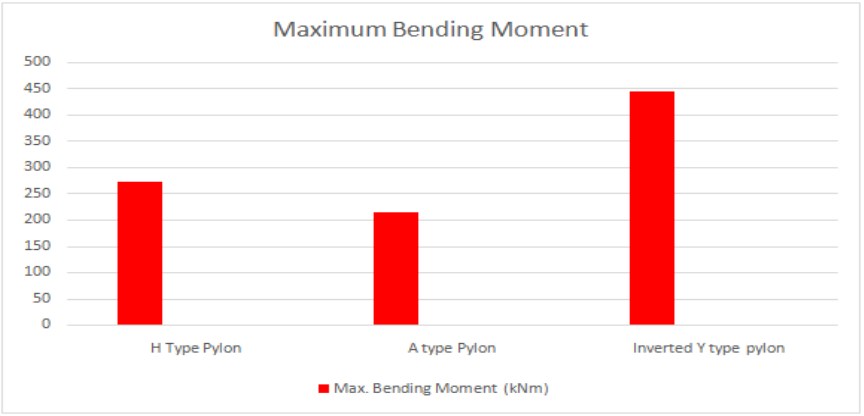

Fig. 8. Maximum Bending Moment comparison for different type of pylons

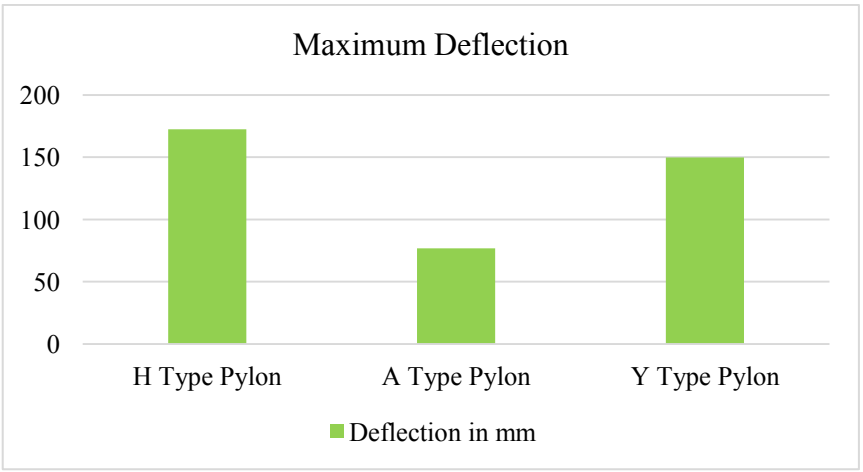

Fig. 9. Maximum Deflection comparison for different type of pylons

The specific results that can be drawn from this analysis are numerated as follows:

- The shear force is maximum in A-type pylon than in inverted Y-type pylon, and is least in H-type pylon design.
- The bending moment is maximum in inverted Y-type pylon design of cable stayed bridge.
- The deflection is maximum is H-type pylon design followed by inverted Y-type pylon design, whereas is least in A-type pylon design of cable stayed bridge resulting in maximum efficiency.

5 Conclusions

In this paper, the designing and analyses of different types of pylon of cable stayed bridge is done with the help of software STAAD Pro. The different types of pylons that are taken into account are H-type, A-type, and inverted Y-type respectively. The shear force, bending moment, deflection for three different types of pylons of cable-stayed bridges are compared with each other and the outcome of these comparisons are noted. Firstly, the designing for H-type pylon, followed by that of A-type pylon and lastly the designing of inverted Y-type pylon is completed. Then effect of these different pylon design on the stability and efficiency of bridge components are investigated and compared. At the end, the most efficient pylon type out of all these three designs is proposed. The results indicate that A-type pylon design for cable stayed bridge is more efficient then two other pylon design.

Shear force also referred as the unbalance force, which is a result of transmission of load from beam to column. In our analyses maximum shear force is observed in A-type pylon i.e., 605.876kN, 468.210kN for inverted Y-type and H-type pylon design i.e., 508.93kN**.** In terms of bending moment, it is observed that maximum bending is in inverted Y-type pylon i.e., 444.329kN-m, 271.430kN-m for H-type pylon whereas minimum is observed in A-type pylon i.e., 213.8kN-m which shows that this pylon design is more economical in comparison to other types as bending moment is directly proportional to the amount of reinforcement requirement. In case of deflection, it was observed that we observed that pylon type H has maximum deflection i.e., 172.5mm, followed by inverted Y-type pylon design i.e., 149.8mm,whereas it minimum in A-type pylon design, i.e., 76.9mm, which concludes that A-type pylon is most suitable and stable section in comparison.

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