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Analysis of A Cable Stayed Bridge Considering Different Pylons Arrangements

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ABSTRACT

A bridge is a structure, which connects two ends of obstacles such as river, valley, other road and railway lines for the purpose of providing small routes as possible for safe journey. There are many different designs that each serve a particular purpose and apply to different situations. A cable stay bridge consist of cable, deck, pylon and foundation. Literature survey revealed that comparative study of different type of pylon for cable Stay Bridge.

In this Project work, live project of cable stay bridge i.e. (Raja Bhoj Setu), Bhopal is considered. It is located at V.I.P. road. It has been designed, constructed considering details and hydraulic data as per site. In this study analysis of different types of pylon in cable stay bridge i.e. H-type, A-type and Y-type is presented to determine the most suitable type and compare it with the executed H-type pylon.

It is concluded through this study that A-type pylon is comparatively more stable, economical and efficient in bearing load whereas H-type is second best and Y-type is third in comparison. On the basis of various parameters considered.

Keywords: Staad, Analysis, Cable stay, Pylon, Finite element analysis, IRC loading, Deflection, Bending, Forces.

I. INTRODUCTION

Bridge is an important structure required for the transportation network. Now a day with the fast innovation in technology the conventional bridges have been replaced by the cost effective structured system. For analysis and design of these bridges the most efficient methods are available. Different methods which can be used for analysis and design are AASHTO, Finite element method, Grillage and Finite strip method.

Vehicle load capacity analysis of a bridge superstructure is required as per I.R.C. and manual for standards and specifications for Indian road congress norms. Its main purpose is to assure, that bridge is safe for the user or public. By the load capacity analysis, a bridge might be found to be incapable of securely conveying some legal loads.

Furthermore, when the loads are beyond the range of permit loads need to be utilizing a particular structure, load limit analysis can give answer about which loads are securely satisfactory. STAAD.Pro is efficient and accurate software used for concrete and steel bridge analysis and design. The advantage of the software is that it incorporates this provision of Indian Road Congress (IRC) bridge design specifications and railway specifications. STAAD.Pro is a general purpose structural analysis and design tool with applications chiefly in the building industry - commercial buildings, bridges and highway constructions, industrial constructions, chemical plant structures, dams, retaining walls, foundations, culverts and other embedded structures, etc. STAAD. Pro is basically based on Finite Element Analysis for carrying out the computations for Analysis and Design of a Structure.

Figure 1: Bridge

Bridge failures

The collapse of the Tacoma Narrows Bridge is perhaps the best recorded and documented bridge failure in the bridge engineering history. The spectacular and prolonged failure process was captured on extensive live footage, giving a unique document for the investigation committee as well as for the engineering society at large. The footage has since then been used in civil engineering classes all around the world for educational purposes. Consequences of neglecting dynamic forces in the construction of suspension bridges can be clearly observed.

The flexibility of the bridge decks (i.e. their lack of stiffness) can cause not only problems with vibration and swaying during wind loading, but also, when marching troops are passing. Through the combined effect of heavy wind and the steps interlocking with the Eigen frequency of the bridge, a large troop of marching soldiers in 1850 set the suspension bridge over the river Maine at Angers in France in violent vibrations. The bridge collapsed and 226 soldiers lost their lives.

Cable stay bridge

Many constructions of cable stay bridges have been auspiciously completed around over the world from last two decades of the 20th century. Due to their highly substantial display & incomparably appropriated structural materials, cable stay bridges have been taken as one of the most popular type of bridges in last decades. With the increase in the length of span of bridges, the modern cable stay bridges are more sufficient & extensible strong enough to the wind forces as compare to ever. A typical cable stay bridge consists of deck with one or two pylons uplifted by the piers or the walls in the middle of the span. The cables are connected at some angle to the girder to provide additional supports. The vertical loads on the deck are carried by the cable stays which are in tension. The tensile forces in the stay cables influence horizontal compression in the deck.

The Pylon transfers the forces developed in the cables to the foundation through vertical compression. The design of the bridge is figure out such that the static horizontal forces resulting from dead load are almost balanced to minimize the height of the pylon. Cable stay-bridges have a low center of gravity, which makes them capable in opposing the effects of earthquakes. Cable stay bridges provide outstanding architectural display due to their small diameter of cables and exclusive upper part of structure. It can be constructed by cantilevering action from the tower i.e. the cables act both as temporary and permanent supports to the bridge deck. The advantage of cable stay bridges is that it can be built with any number of towers.

Fig 2 : Pylon types

Shekhar S Patil and Jayant P Patankar (2017 July) (Seismic response of cable stay bridge with different types of pylons of various heights) Illustrated that Cable stay bridge are getting more prominent nowadays in view of good steadiness and rich for long range bridges contrasted with different sorts of bridges. A cable stay bridge is a bridge in which the heaviness of the deck is bolstered by various cables running specifically to at least one towers. Here spotlight is given on the impact of different states of pylons, for example, Single pylon, A sort pylon and Inverted Y type pylon on the seismic reaction of cable stay bridge. The impact of different statures of pylons on the seismic reaction of cable stay bridge additionally considered for study. The bridge range measurements and different parameters are kept steady and just variety fit as a fiddle and tallness of pylon is improved the situation similar investigation of pylon. The 3D bridge demonstrate is set up on Midas Civil and direct powerful investigation is completed. The bridge reaction regarding cable powers, pylon twisting, deck misshapening, era and base shear is acquired. It is discovered that, Single pylon and Inverted Y type pylon are superior to A sort pylon for parameters cable powers, pylon and deck misshapening. Single pylon is more grounded longitudinal way in opposing earthquake drive while Inverted Y type pylon is more grounded sidelong way in opposing earthquake constrain.

Anand Soni et. al. (May 2017) (static analysis of cable stay bridge system using various types of deck profiles) The Innovative deck profile of cable-stay bridge proposed here for an investigation of various sorts of deck profiles by utilizing cable stay bridge framework. The prime target of the present work is to demonstrate an upgraded Cable Stay Bridge with managed support with different highlights, i.e. length to profundity proportion as steady parameter an endeavour is made here to check the cost economy, auxiliary quality of proposed by bridge by checking a proportion of load conveying ability to material necessity separately. The total work comprise an investigation utilizing business programming (MIDAS CIVIL 2016). Static investigation of bridge with variety in deck profiles, i.e., PSC-I Deck, PSC-T bar, PSC-Box supports. Parametric examination will be work out utilizing different unthinkable and graphical shape which features a goal dependent on cost economy perspective as far as quality, usefulness and economy individually are the prime foundation. Here a geometry was taken of "Pandit Dindayal Upadhyay Cable Stay Bridge" which is directly developing on Tapi waterway across Athwa to Adajan.

II. Objectives

The main objectives of the present study are as follows: -

- Study of Cable Stay Bridge with different pylon types under Dynamic Loading Condition.
- To determine the most suitable type of pylon for cable stay bridge located at V.I.P. Bhopal.
- To determine the effect of pylon on deck of bridge.
- To calculate vehicular load as per I.R.C. 70R.

III. Problem Statement

This chapter deals with methodology for calculation of the critical load placing over the considered bridge using finite element method. In this methodology, we have used STAAD-Pro software which is based on the application of Finite Element Method. This software is a widely used in the field of structural design and analysis. Now a day this software is very much friendly for the analysis of different type of structures and to calculate the result at every node & element wise. Analysis for the bridge members, prepared the conceptual dimension geometry of the superstructure which are shown in figure –

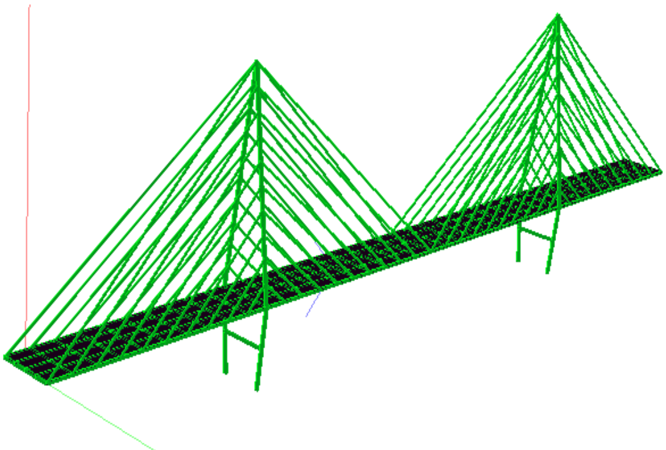


Fig 3: Modelling of structures

Here R.C.C. bridge frame is modeled in analysis tool staad pro in which deck bridge is analyzed and optimized, and I.R.C. loading is considered as class 70R+A loading, dead load as per 875 part-1 and superimposed live load as per 875 part-2 is calculated and applied.

Three cases has been considered for comparative analysis:

- First Cable stay bridge with H-type pylon.
- Second Cable stay bridge with A-type pylon.
- Third Cable stay bridge with Y-type pylon.

All these are prepared as per data for Raja Bhoj Setu bridge at V.I.P. road Bhopal with length 262 m.

Different types of bridge sections considered are as follows:

A. A-type pylon bridge:

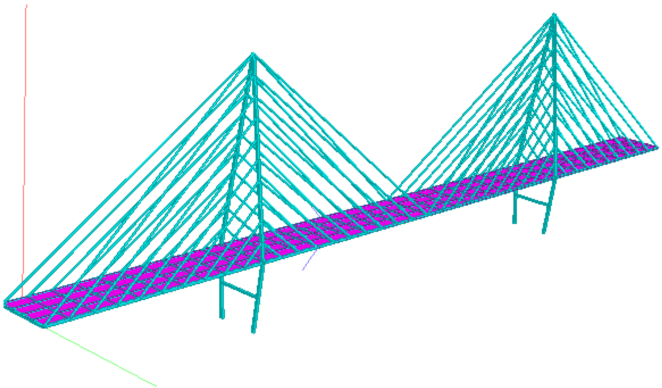


Fig 4. A-type pylon cable stay Bridge

B. H-type Cable Stay Bridge:

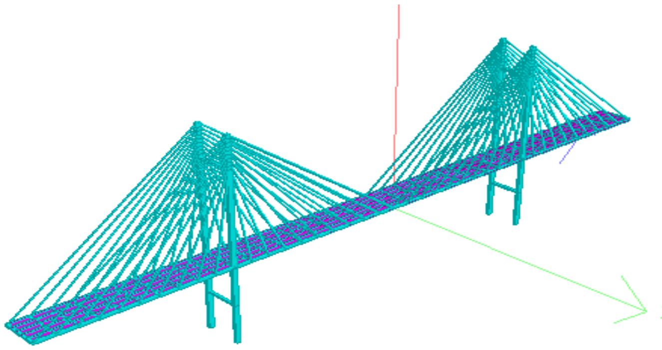


Fig 5. H-type Cable Stay Bridge

C. Y-type Cable Stay bridge

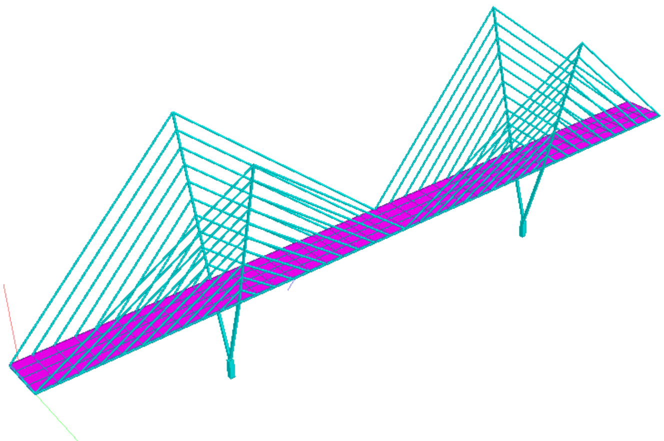


Fig: 6. Y-type Cable Stay Bridge

Step 3: Apply the material property as shown in above figures, after that support condition has been considered at the bearing locations of the superstructure which is fixed support as shown in below figure.

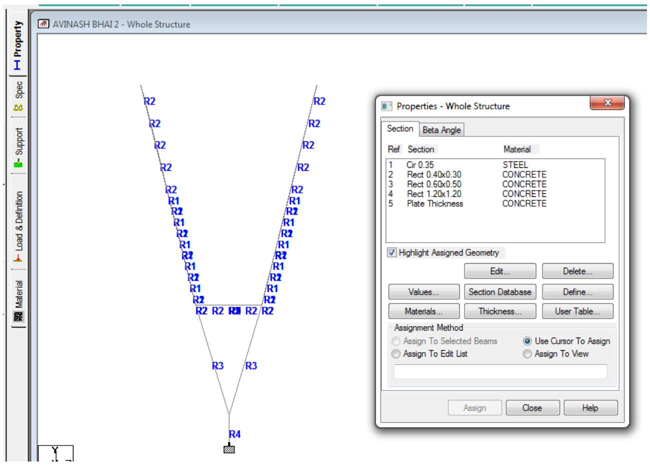


Fig 7. Support condition

Step 4: After apply the support condition, now the next step to be considered for the Deal Load of the superstructure i.e. "self-weight".

Step 5: After apply the Dead Load, now the next step to be considered for the **Equivalent Uniformly Distributed Loads (EUDL)** load.

For Bending Moment, L is equal to the effective span in metres. For Shear Force, L is the loaded length in metres to give the maximum Shear Force in the member under consideration. The Equivalent Uniformly Distributed Load (EUDL) for Bending Moment (BM), for spans up to 10 m, is that uniformly distributed load which produces the BM at the centre of the span equal to the absolute maximum BM developed under the standard loads. For spans above 10 m, the EUDL for BM is that uniformly distributed load which produces the BM at one-sixth of the span equal to the BM developed at that section under the standard loads. EUDL for Shear Force (SF) is that uniformly distributed load which produces SF at the end of the span equal to the maximum SF developed under the standard loads at that section.

Step 6: After apply the EUDL Load, now the next step to be considered for the Moving Live Load (LL) in which include the Breaking Load and Vehicle Load are as follow: -

1) DFC (*Dedicated Freight Corridor*) LOADING FOR BENDING MOMENT [Eccentric & Concentric]
2) DFC LOADING FOR SHEAR FORCE [Eccentric & Concentric]
3) Coefficient of Dynamic Augment (CDA) *Coefficient of Dynamic Augment* FOR PROVIDED DECK LENGTH.

Step 7: After applied all the boundary condition and forces, now the model has to be "Analyse" for getting the results i.e. Axial force, shear force, deflection and support reactions etc.

Step 8: After analysis results designing is followed as per Indian Standard 456:2000 R.C.C. design and optimization of each case is done to provide its economical section for same loading and geometry in all the cases.

Step 9: After optimization process comparative results are drawn in all cases to determine the best one with the help of graph using M.S. Excel.

Table 1. Description of Structure

S.No.	Description	Value
1	Length of Bridge	262 m.
2	Number of bays in X direction	52
3	Number of bays in Z direction	32 m
4	Width of the bridge section	15.90 m
5	Bay width in Z direction	3 m
6	Support type	Fixed support

The Bridge is of structural plan in X direction is 262 m and in Z it is 15.9 m.

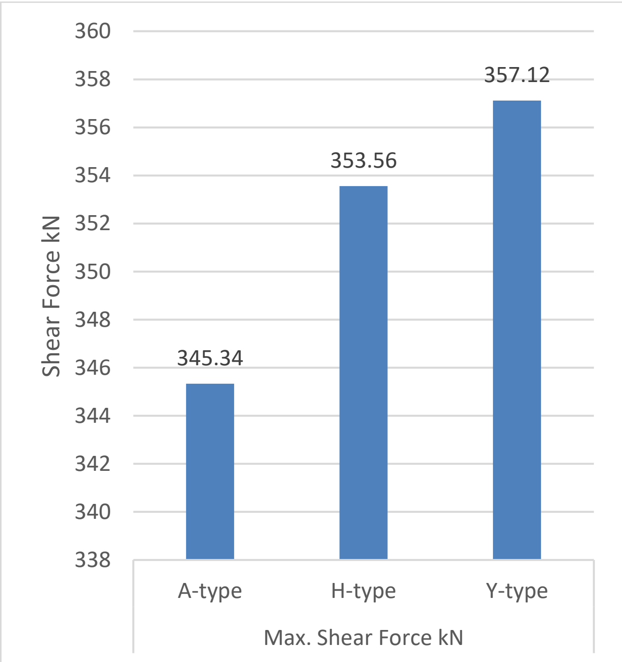
Technical Specifications

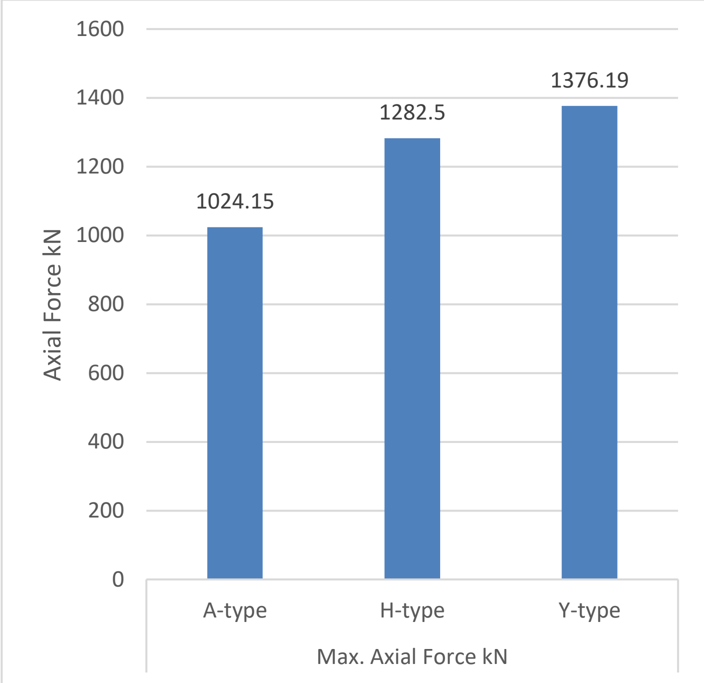
In this problem standard material properties are considered which is given below table:

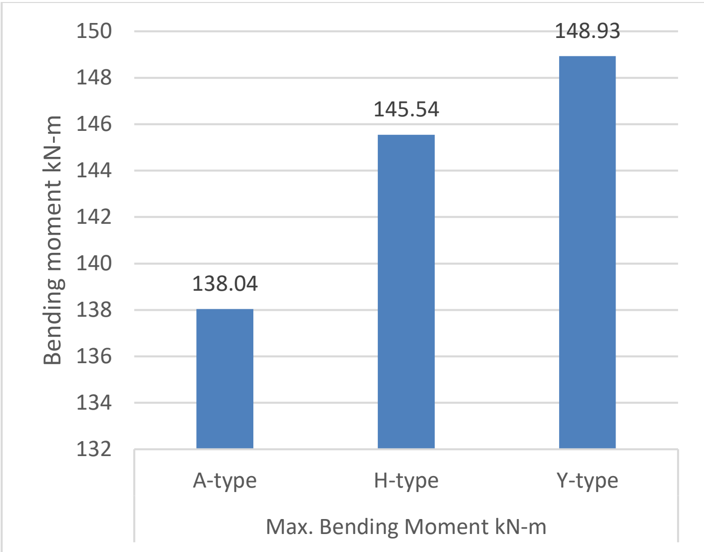
Table 2. Property of material

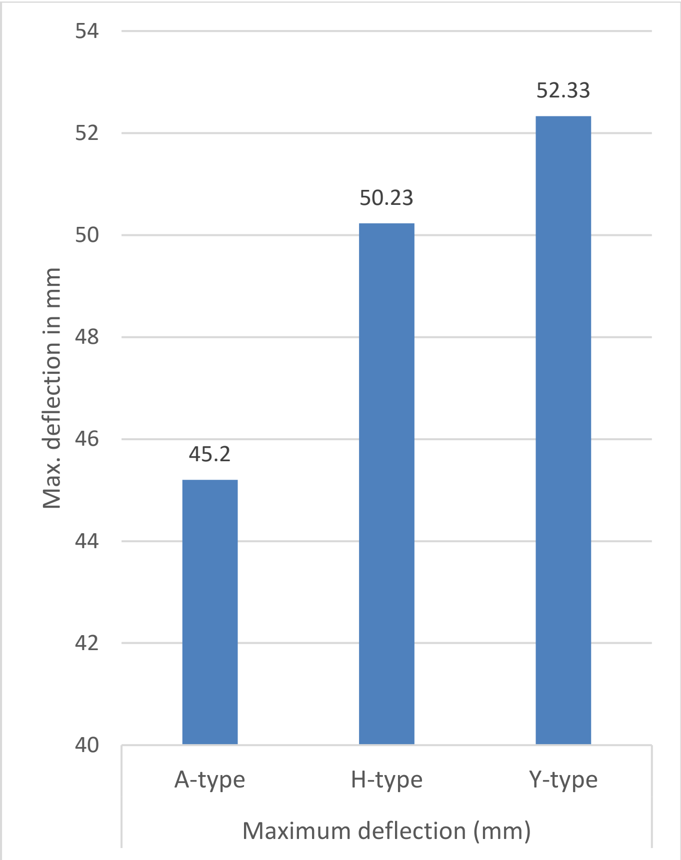
S.No.	Description	Value
1	Sections	Standard
2	Young's modulus of steel, Es	2.17×10^4 N/mm^2
3	Poisson ratio	0.17
4	Tensile Strength, Ultimate Steel	505 MPa
5	Tensile Strength, Yeild Steel	215 MPa
6	Elongation at Break Steel	70 %

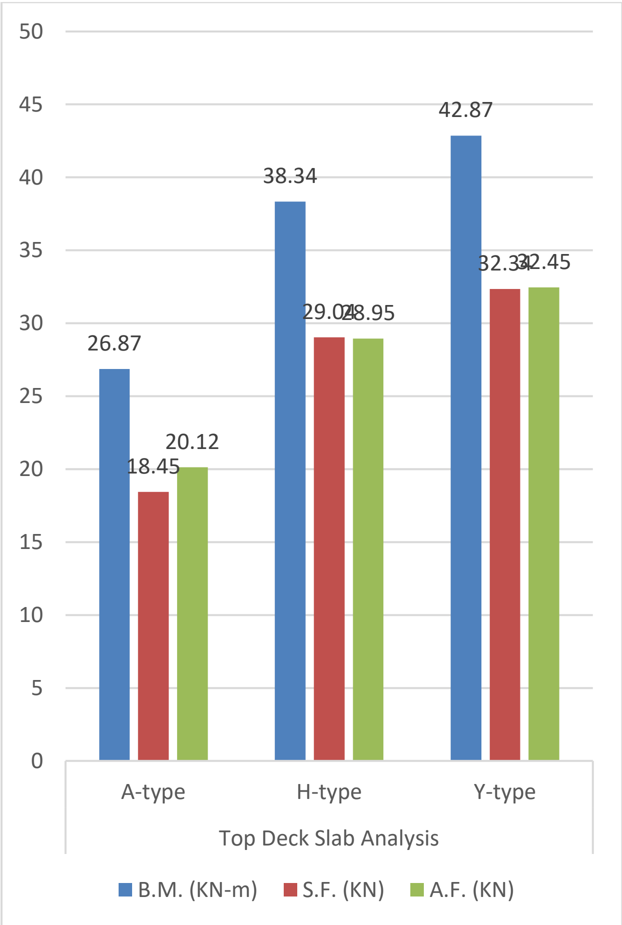
IV. Analysis Result











V. CONCLUSION

Shear Force

Shear force in known as the unbalance force observed due to transmission of load from beam to column, in our study maximum value is observed in Y-type pylon i.e. 357.12 kN, whereas minimum in A-type pylon i.e. 345.34 kN.

Axial Force

Axial force is known as the vertical force observe in piers, this force is meant to distribute load from pier to earth. In our study maximum axial force is observed in Y-type i.e. 1376.19 kN, whereas minimum in A-type pylon i.e. 1024.15 kN, thus A-type pylon requires minimum cross sectional piers for load distribution.

Bending Moment

In terms of bending moment, it is observed that maximum bending is in Y-type pylon i.e. 148.93 kN-m, whereas minimum is observed in A-type pylon i.e. 138.04 kN-m which shows that A-type pylon is comparatively most economical in comparison as bending moment is directly proportional to reinforcement requirement.

Deflection

In case of deflection we observed in above chapter that maximum deflection is obtained in Y-type pylon 52.33 mm whereas least is observed in A-type pylon 45.20 mm, which concludes that A-type pylon is most suitable and stable section in comparison.

Deck Analysis

In deck analysis using Finite element method it can be observed that analysis is resulting in small nodal distribution of slab for proper analysis, in which number of nodal are resulting forces out of which maximum value is considered. It is observed in fig.

5.5 that resultants are minimum in A type pylon case whereas maximum in Y-type pylon case.

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