Parametric Study of Extradosed Bridge for Effect of Support Reaction

Rohit Ghorpade[1], Dr. M.M. Murudi[2]

[1]*PG Student, Department of Civil Engineering, Sardar Patel College of Engineering, Andheri (W) Mumbai-400058, Maharashtra, India*
[2]*Professor, Department of Civil Engineering, Sardar Patel College of Engineering, Andheri (W) Mumbai-400058, Maharashtra, India*

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Abstract - *Extradosed Bridge resembles similarity to cable- stayed bridges, the difference lies in the tower height and the depth of the girder. Since the introduction of this new type of bridge by J. Mathivat in 1988, these kinds of bridges supported by cables have been constructed globally. The paper aims at studying the Base reaction variation in the Pier due to varying cable geometry, tower height and pylon type.*
IRC 6: 2017 has been used for loading. Cable geometry will consist of Radial, Mix and Harp type of cable arrangements.

***Key Words*: Extradosed Bridge, Tower, Cable geometry, MIDAS Civil, Support Reaction**

1. INTRODUCTION

Extradosed bridge is a midway between a cable-stayed bridge and PSC-box girder bridges. They can be peculiarly distinguished from cable stayed bridge using the Pylon height parameter. The cable-stay angle with the deck is smaller compared to any cable-stayed bridge. The cable stays are connected externally to the deck and due to lower tower height, the stays act as a prestressing medium for the box girder. Generally suitable for a span of 100-200 m, extradosed bridges are preferred. Stays in the extradosed bridges can be stressed to a relatively high level, similar to use in prestressed girder structures, since the stress variation under live loads in stays is usually lower in comparison with the cable-stayed bridges. [1][2]

2. LITERATURE REVIEW

1) Chowdhury M.S., Rahman M. M., Rana M. S. in their research, "Study on Extradosed Bridge and It's Structural Behaviour" studied ten variety of extradosed models and analysed them using STAAD Pro V8i software. They had some vital conclusions to be made which were as listed below,

Cables anchored with box Girder increase the compressive force of girder and allows the box girder to carry a huge load with a very long span and lower tower height.

1. Ten different prototype models were used and analysed by analysis software STAAD PRO V8i.
2. All section and dimension are same except the tower height. Reduced cable inclination leads to an increase in the axial load in the deck.
3. As the cable angle increases, the compressive force in the girder decreases.
4. Deflection of girder and cables are important factor for selecting an optimum tower height.
5. Maximum compression of girder occurs when the cables are in a higher tensile force.

Thus, the key findings were, only Gravitational loads have been considered for the analysis. Section properties were same for all models and various lateral and longitudinal arrangements of tower were not considered for the analysis [3]

2)Barua S. and Jubary A., worked on the topic, "Effects on cable configuration due to change in different geometric parameters of extradosed bridges" and prepared the model for Third Karnaphuli Bridge using the software Csi Bridge. Observations were,

1. Bridge considered for analysis was Karnaphuli Bridge, Dhaka.
2. Analysis was done using the software CSI Bridge V15 (SAP 2000)
3. Load combinations were considered as per AASHTO LFRD Design Specifications.

Thus, it could be noted that, increase in span length caused cable inclination to be decreased thus vertical component of the cable force was reduced. Also increasing the span length (More than Karnaphuli Bridge) resulted in increase in extradosed cables to balance the extra dead load [4]

3) Biliszczuk J., Onysyk J., Barcik W., Toczkiewicz R., Tukdendorf A., presented their report on the topic, "Extradosed bridges in Poland – Design and construction" to quote the comparison between various parameters of cables stayed bridge and extradosed bridge constructed worldwide. Author has studied the geometrical parameters of various extradosed bridges in Poland ranging from short, medium and long spans bridges. Based on the data, few geometrical parameters have been quoted such as, L/H is generally in the range 6~12. H/D is observed as 3~4 where,

L – Longest span of the bridge

H- Tower Height in meters

D – Depth of the girder over the Supports

Key findings from this research paper were as follows,

1. Relationship between Tower Height and Span of the bridge is a linear variation.
2. Cable Stayed Bridges, the tower height is more compared to Extradosed Bridge.

Thus, from the papers it can be seen that Extradosed bridges can even be competitive when compared to a span of 200m bridge [5]

4) Collings, D., and Gonzalez, A. S., in their research," Extradosed and cable-stayed bridges, exploring the boundaries" helped in understanding the clear difference between an Extradosed bridge and a Cable stayed bridge. An extradosed bridge is a structure where the permanent loads are shared between the stays and girder, but where the girder carries the majority of the live load (βp is 40 to 80, βv is 10 to 50).

The load distribution ratio (β) is defined as,

$$\beta = 100\left(\frac{\textit{VERTICAL LOAD CARRIED BY STAYS}}{\textit{TOTAL VERTICAL LOAD}}\right)$$

Key findings led to the understanding that the load distribution ratio, (β) plays a major distinguishing role and hence has to be studied [6]

4. OBJECTIVES OF CURRENT STUDY

1. Modelling 144 m Extradosed Bridge using commercial software.
2. Support reaction variation due to cable geometry, Tower height, Pylon geometry.
3. Tower height will be studied in the range of L/8 to L/15.
4. Analyzing Support Reaction results obtained for all models considered.

5. MODELLING DATA

The Extradosed Bridge which is to be analyzed has a clear span of 144m between the two pier supports, whereas the cantilever projections on both the sides are 72m each. Thus, total span to be modelled is 288m.

- BRIDGE TYPE: EXTRADOSE BRIDGE
- C/C SPAN: 144m

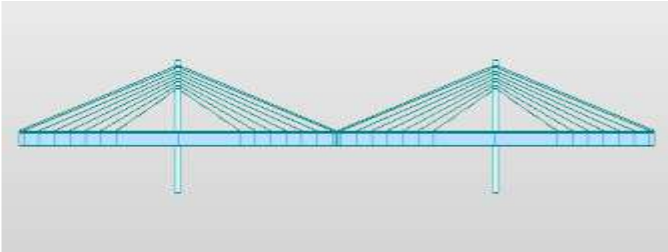


Figure 1 Finite element representation of 144m long Extradosed Bridge

Analysis is done using MIDAS Civil commercial software and Fig. 1 shows the elevation of the model. Data considered for the analysis is as follows;

- Deck Type: PSC Box Girder
- Girder Depth: 3m
- Carriageway: 7.5m
- Vehicular Loading: As per IRC 6: 2017
- Cables Used: 15k19

5.1 ASSUMPTIONS

Table 1 Material Properties of the bridge

Name	Parameter	Definition	Properties
Steel	Es	Modulus of elasticity	200 GPa
	γs	Unit weight	77 kN/m^3
	µs	Poisson's ratio	0.3
Concrete	Ec	Modulus of elasticity	35.35 GPa
	γc	Unit weight	25 kN/m^3
	µc	Poisson's ratio	0.2
	fc′	Compressive strength	50 MPa
Cables	Esc	Modulus of elasticity	195 GPa
	γcable	Unit weight	78.5 kN/m^3
	Tccable	Ultimate tensile strength	1860 MPa
R/f Steel	*fy*	Yield strength	500 MPa
Asphalt	γasphalt	Unit weight	22 kN/m^3

5.2 MODEL DESCRIPTION

Total 18 different models are analyzed as mentioned in Table 2, and based on the same, results have been concluded. Span length od 144m is kept constant for all the models, where as parameters varied are as follows,

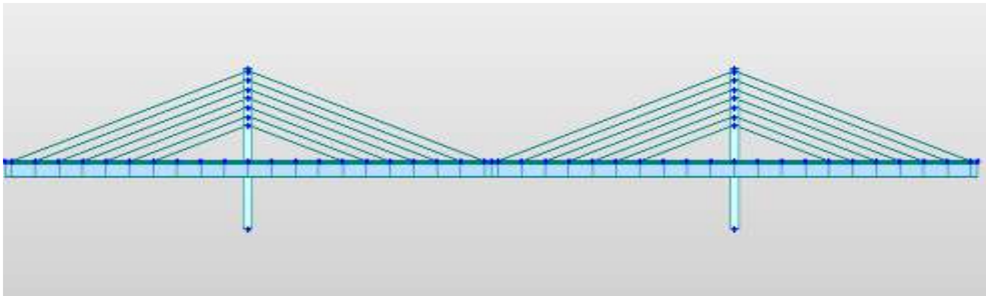
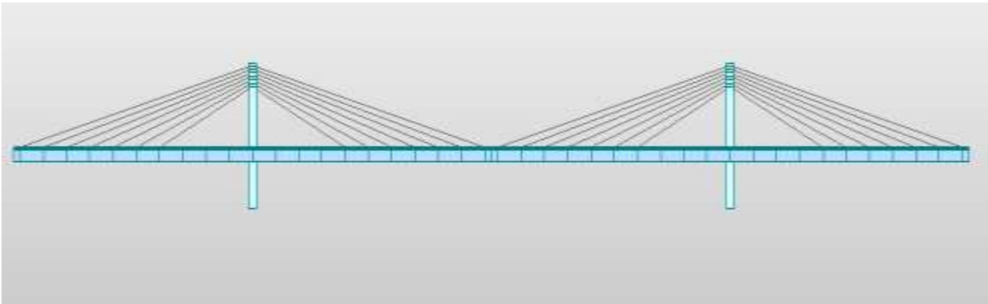
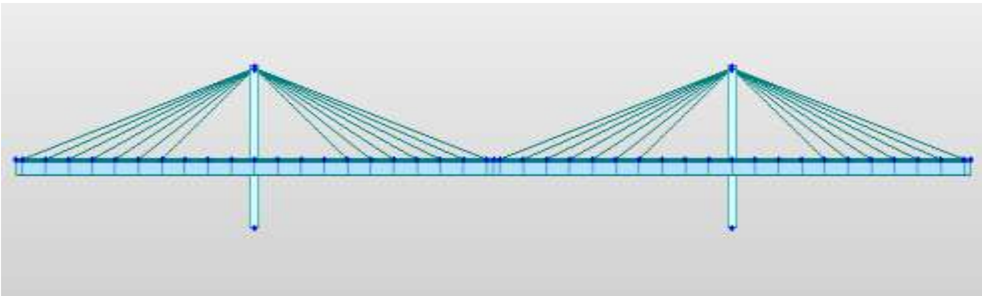
1. Stay Cable Arrangement – Three different arrangements have been incorporated viz., Radial, Harp and Mix.
2. Pylon Height – 10m, 12m, 15m
3. Pylon type – Single pylon, H-shaped pylon

Table 2 Nomenclature

I- Single Pylon			H-Shaped/ Double Pylon		
HARP	MIX	RADIAL	HARP	MIX	RADIAL
1-H(L/8)	1-M(L/8)	1-R(L/8)	2-H(L/8)	2-M(L/8)	2-R(L/8)
1-H(L/12)	1-M(L/12)	1-R(L/12)	2-H(L/12)	2-M(L/12)	2-R(L/12)
1-H(L/15)	1-M(L/15)	1-R(L/15)	2-H(L/15)	2-M(L/15)	2-R(L/15)

The Stay Cable Arrangement is as below,

Table 3 Cable Arrangement classification (Courtesy: Midas Civil)

Harp Arrangement	
Mix Arrangement	
Radial Arrangement	

6. RESULTS AND DISCUSSIONS

From the above Table 4, it can be noted that as the pylon height is increasing from 10m to 18m, support reactions are also attracted more. The results are checked for the LCB1 case i.e. Load Combination 1, where cable tuning is not taken into consideration. When the Cable arrangement is considered it can be distinctly quoted that Radial shape has more support reaction generated when compared to mix and harp.

Harp shape thus with pylon height of 10m has the least support reaction in case of a Single Pylon.

Now, studying Table 5, Forces by H-pylon attracted are very less compared to Single. The results are similar to Single pylon and with increase in height the axial forces increase and cable arrangement certainly has varying effect on support reactions.

Table 4 Support Reaction for Single Pylon Case

PYLON HEIGHT	CABLE TYPE	Support Reaction for **Single Pylon (kN)**
L/15 (10m)	HARP	29414
	MIX	29486
	RADIAL	29875
L/12 (12m)	HARP	29903
	MIX	30058
	RADIAL	30353
L/8 (18m)	HARP	31414
	MIX	31754
	RADIAL	31968

Considering the angle inclinations of the stays, Radial has the maximum inclination with the deck and thus the vertical components of the stay cables are dominant. This must be resulting in higher reaction at the base. As a result of which, Radial arrangements seems to be attracting heavier base reactions and Harp with least inclinations has less base reaction for both Single as well as H-pylon models.

Table 5 Support Reaction for **Double -H Pylon** Case

PYLON HEIGHT	CABLE TYPE	Support Reaction for **H-Pylon (kN)**
L/15 (10m)	HARP	16515
	MIX	16752
	RADIAL	16795
L/12 (12m)	HARP	16841
	MIX	17078
	RADIAL	17284
L/8 (18m)	HARP	18303
	MIX	18514
	RADIAL	18636

As the height of the tower increases, the inclinations are further going to increase resulting in higher base forces for higher tower height. Thus, high tower heights will lead to heavier requirement of foundation to tackle the base reactions generated.

Plotting a graph for the data in Table 4,

Figure 2 Support Reaction (Single Pylon)

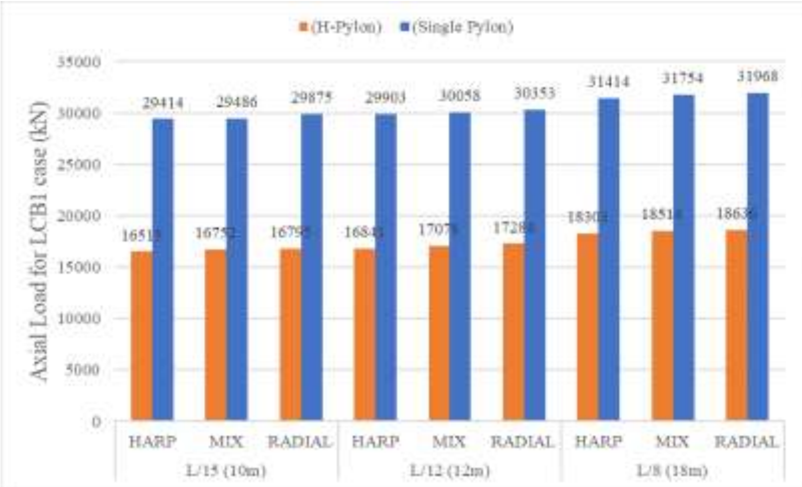


Figure 3 Comparison of Support Reaction for all the 18 cases

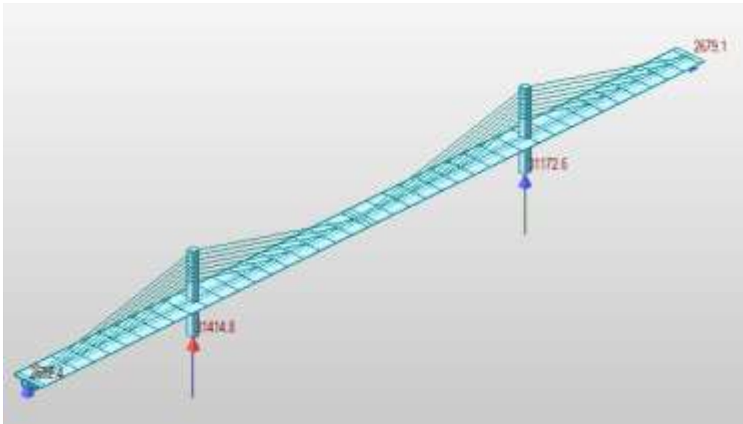


Figure 4 Typical result dialogue box for 1H-L/8 case (Courtesy: Midas Civil - 2019)

7. CONCLUSIONS

- Single Pylon attracts higher Support reaction compared to H-shaped pylon for all the cases analyzed.
- Harp cable arrangement is the best suited in case of base reactions.
- As the tower height increases, base forces increase, thus opting for higher tower height can turn out uneconomical.
- When the soil bearing capacity is less, double pylon with Harp arrangement and lower tower height is the most optimum combination available.

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BIOGRAPHIES

Mr. Rohit B. Ghorpade
M. Tech – Structural Engineering
Sardar Patel College of Engineering,
Andheri West,
Mumbai – 400058
Year – 2017-2019

Dr. M. M. Murudi
Professor, Vice Principal
(Head of Department - Civil)
Sardar Patel College of Engineering,
Andheri West,
Mumbai – 400058