Wind Analysis on Cable Stayed Bridge

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ABSTRACT

Cable stayed bridges have been popular in recent decades for providing free space between two piers for the movement of ships and other water bodies; thus, the concept of cable stayed bridges is popular in this century. The conceptual design of a bridge structure is determined by the structure's reliability, serviceability, visual appearance, and cost. The Cable Stayed Bridge is the best design example of a bridge structure that meets all of the following requirements with remarkable efficiency. Wind Analysis is done on Cable Stayed Bridge and then the result is compared with wind analysis on Single Tied Arch Bridge. The bridge is considered in Zone II and all the Clauses in this work are from IRC 6-2016. The prepared geometry of model of cable stayed bridge and tied arch bridge is analysed in FEM software MIDAS Civil.

Keywords: Cable Stayed bridge, Tied Arch bridge, Wind Analysis.

1. INTRODUCTION:

Bridges are undeniably important in the evolution of civilization. We have many different types of bridges, ranging from prehistoric log bridges to modern cable stayed bridges, depending on the total length of the gap to be bridged over, the type and volume of traffic, the importance and expected life of the bridges, the condition of the soil bed, the economy involved, and so on. Long spans have always been difficult for structural engineers to cover. Large Arch bridges, cable stayed bridges, and suspension bridges are particularly effective at covering vast spans thanks to a better understanding of material properties, increased control over building procedures, and the development of high-speed computers.

Towers/pylons, which are the structure's load-bearing parts, support a cable-stayed bridge. Cables run between the pylons and connect them. A cable-stayed bridge is supported by towers/pylons, which are the structure's load-bearing elements. From the pylons to the deck below, cables are linked. Either from the top of the tower or from various positions along the column. This forms a fan-like design when joined at different locations along the column. Many people connect cable-stayed bridges with this feature. This style of bridge is typically utilised for distances that are greater than cantilever bridges but shorter than suspension bridges. One of the most significant drawbacks of this style of bridge is that it is prone to flooding.One of the main issues with this type of bridge is that the central connection of the cables can place horizontal pressure on the deck. Therefore, the deck structure needs to be reinforced to withstand these ongoing pressures.

The tied arch bridge is an intriguing design that has a metallic arch structure supported by vertical ties between the arch and the deck. A bottom chord connects the tips of the arch construction. This works in the same way that a bowstring does. The vertical ties convert the downward pressure applied to the bridge deck by the arch construction into tension. Many people believe that the abutments are responsible for keeping the linked arch bridge and arch construction in place. The decking/strengthened chord, on the other hand, is what joins the arch's tips. The best example is a bowstring that absorbs pressure and keeps both sides of the bow in contact until it is released.

2. LITERATURE REVIEW

Various analysishas been performed on Cable Stayed and Tied Arch Bridges. With some further investigations many research scholars had given results for different types of analysis in different FEM soft wares.Following literature review shows some of the studies done by researchers.

Shubham Garg (2021) designed a cable stayed bridge and performed analysis on it by considering seismic load and wind load by changing the cable position. This analysis was done in STAAD Pro. The obtained results for different cable profile were analyzed and compared to obtain optimum position.**Rahul Babu (2017)** has focused on the parametric investigation on the different wind induced vibrations and therefore the response of cable stayed bridges under wind load. **Nicholas P. Jones (2008)** has discussed about wind effects on long span cable stayed bridges. In order to insure the reliability of predicted response, the input parameters, such as wind conditions at the site and modal properties of the bridge were also calibrated using corresponding measured quantities.**Bernardo Morais da Costa(2013)**hasdesigned a network arch bridge. His aim was to design and perform analysis of the hanger arrangement and structural stability. A comparative analysis with other types of hanger arrangements is also performed.**Mi G Chorzepa (2017)**The study is carried out by completing a modal analysis with finite elements and focusing on the global bridge response and cable vibrations. Another advantage of modal analysis is that bridge degradation is often reflected in changes in the modes and frequencies of vibration. As a result, these findings could be valuable in assessing wind-related damage.

3.MODELLING AND ANALYSIS

3.1 Geometry of Bridge

- Span Length = 520 m
- Main span length = 360 m
- No of Cables = 200 no.
- Width of Bridge = 24.24 m (6 lanes)
- Height of Pylon (from base) = 106.374 m
- Type of Cable Arrangement = Fan Type
- Shape of Pylon = H- shape

3.2 Material Properties:

Material Name	Type	Grade	Elasticity (kN/m^2)	Poisson Ratio
Girder	RCC	M60	38729833	0.2
Cable	Steel	Fe345	$2.1x10^5$	0.3
Pylon 1	Steel	Fe345	$2.1x10^5$	0.3
Pylon Transverse beam	Steel	Fe345	$2.1x10^5$	0.3
Pylon-2	Steel	Fe345	$2.1x10^5$	0.3

3.3 Sectional Properties:

Section Name	Section Dimension Width(m) Height(m)	Type	Cross Sectional Area(m^2)
Girder	0.3	RCC	0.9
	3		
Cable	0.3	Solid Circular	0.0707
PTB	4	Solid Rectangular	16
	4		
Pylon-2	3	Hollow Rectangular	4.08
	3		
Pylon	4	Hollow Rectangular	8.16
	4		

3.4 Loads Acting On Bridge

3.4.1 Super Imposed Dead Load:

SIDL Loads like Barriers, Footpath and kerb taking as $0.5kN/m^2$

Asphalt Density = $22.00 kN/m^3$

Assume, Wearing Coat = 80mm

SIDL Load = 22 x 0.08 =$1.76 kN/m^2$

Total SIDL Load = 1.76 + 0.5 = $2.26 kN/m^2$

Total Width of Deck = 35m

SIDL Load along Deck = 35 x 2.26 = 79.10 kN/m

Total Factored SIDL = 1.5 x 79.10 = 118.65 kN/m

3.4.2 Live Load:

In this parametric study, moving loads on cable stayed bridge are taken as per IRC-6:2016 guidelines. This code defines the type of vehicle and number of vehicle for bridges. Class A and Class 70R vehicle load applied on the bridge.

3.4.3 Wind Load:

We had applied wind load according to IRC 6-2017 Considering Zone wise data wind load is calculated and applied as follows,

WL Calculations:

Basic wind speed = 31.4 m/s … (clause no. 209.2 Table 12)

C/S area of tie beam = 1.62E-0.1= 0.1617 m^2

G (GusFactor) = 2

Cd (coefficient of dynamics) = 0.8 … (clause no. 209.3.3, Annexure C Table C-1)

b (length of section) = 1.344 m

d (depth) = 1.411 m

b/d = 0.952516

P_z = 8.123808 N/m^2

Therefore,

Transverse Wind load = 8.123808 N/m^2

Longitudinal Wind Load = 8.123808/2 = 4.061904 N/m^2

3.4.4Defining Pre stress Force for Cable:

The initial Pre stress force of a cable is calculated using the below empirical formula: F = σ x A x 60% Where, F is the initial pre stress force, σ is the yield stress of the cable and A is the cross- sectional area of the cable.

3.4.5The Boundary Conditions

3.5 The boundary conditions of a finite element model are always difficult to model accurately, just as they are for real structures. In this project, we used approximate boundary conditions. The connection between the pier and the pylons has been deemed a permanent one. The connection between the cables and the bridge deck has been regarded pinned since the cable cannot withstand rotating resistance.

3.6 ANALYSIS

1.5.1 Analysis on Cable Stayed Bridge:

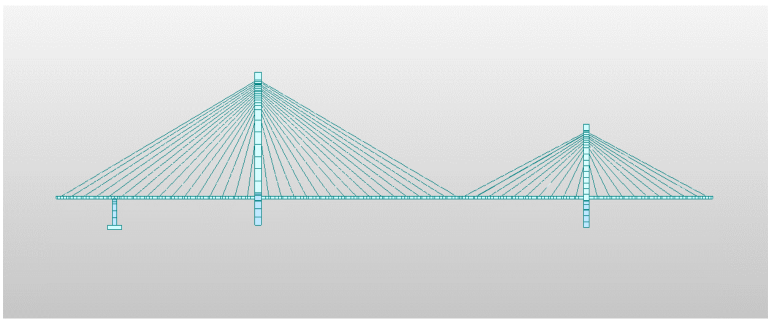

Figure 1. Section View of Cable Stayed Bridge.

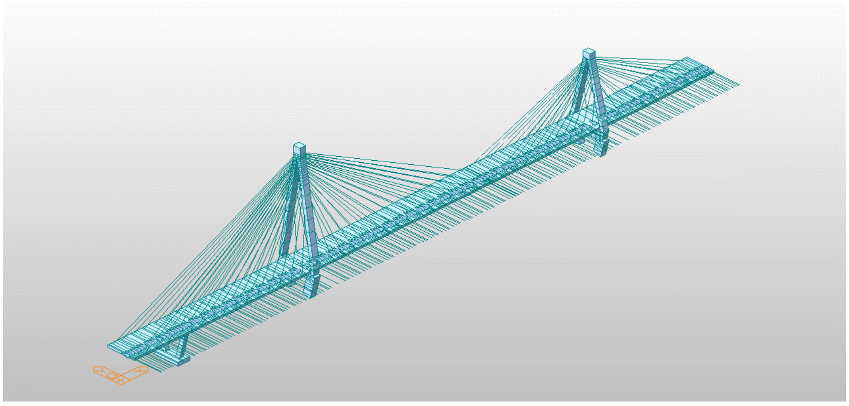

Figure 2. Transverse Wind Load on Cable Stayed Bridge.

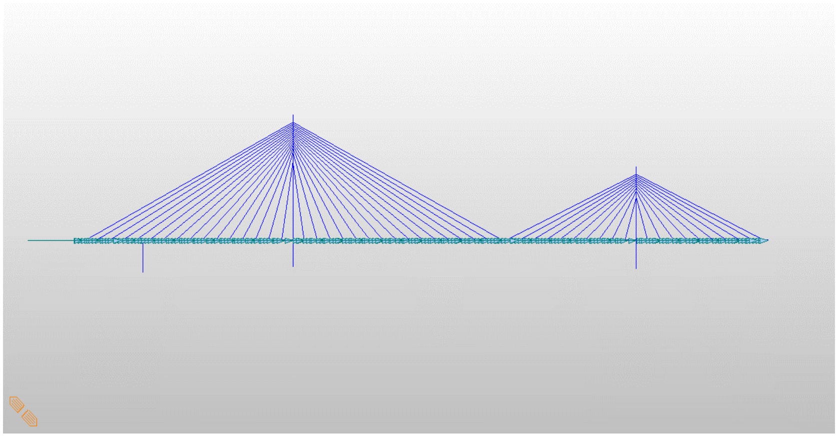

Figure 3. Longitudinal Wind Force on Cable Stayed Bridge.

1.5.2 Analysis on Single Tied Arch Bridge:

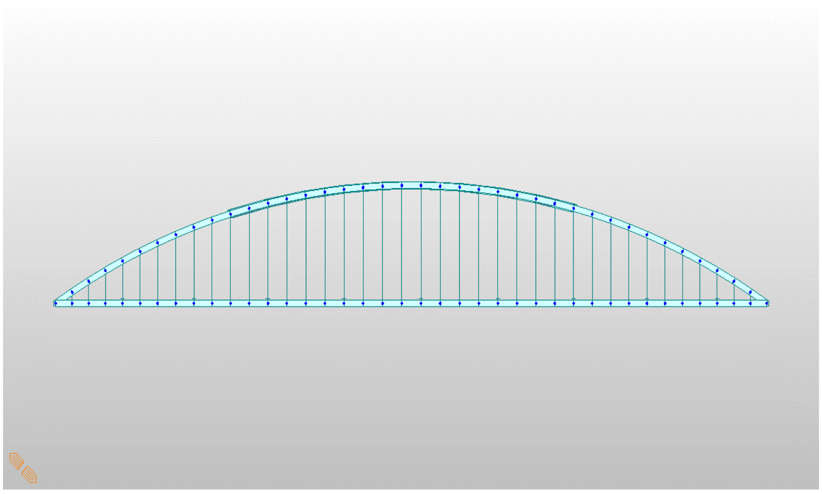

Figure 4 Section View of Single Tied Arch Bridge.

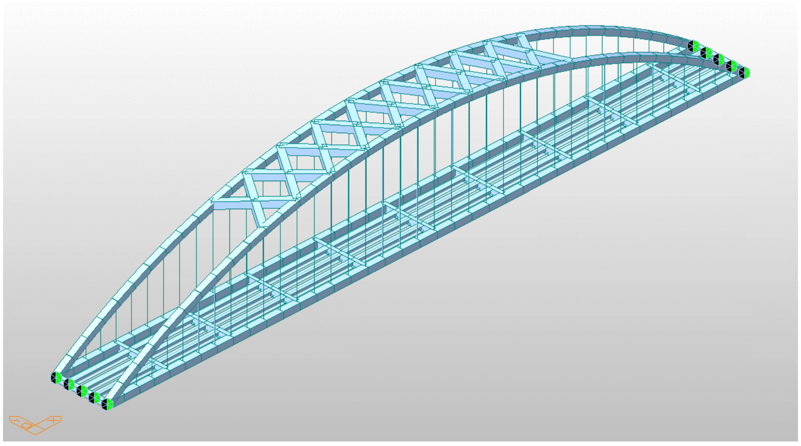

Figure 5. Supports of Single Tied Arch Bridge.

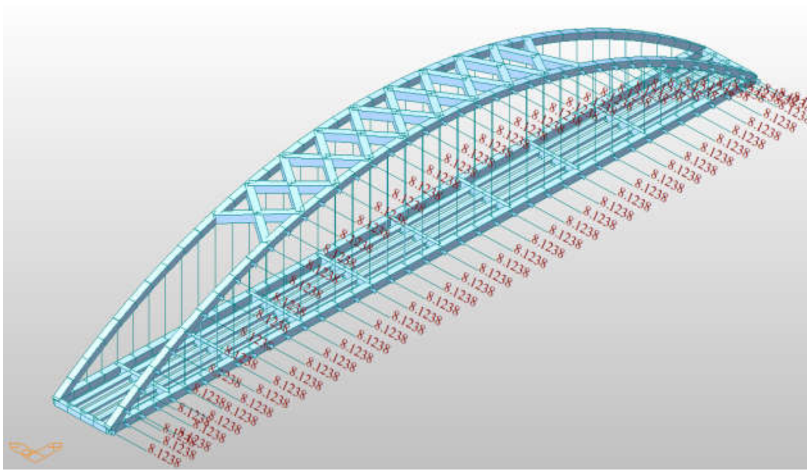

Figure 6. Transverse Wind Load on Single Tied Arch Bridge.

1.6 RESULTS

3.6.1Results of Wind Analysis of Cable Stayed Bridge:

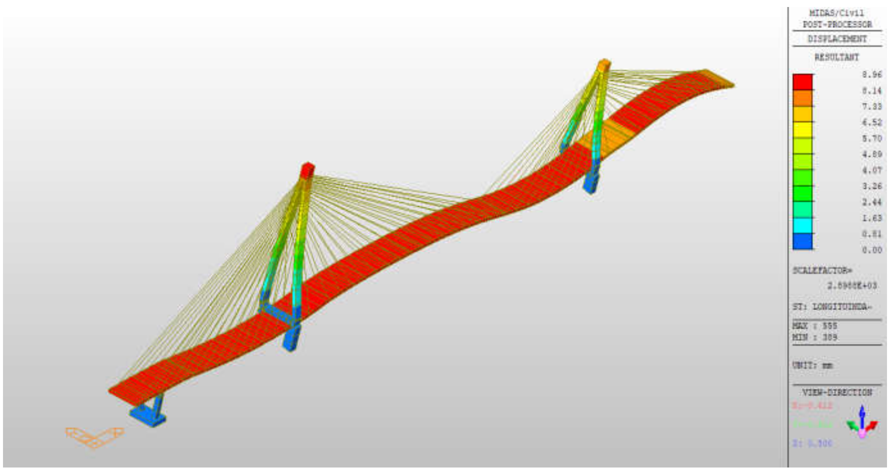

Figure 7. Deformation due Longitudinal Wind Force

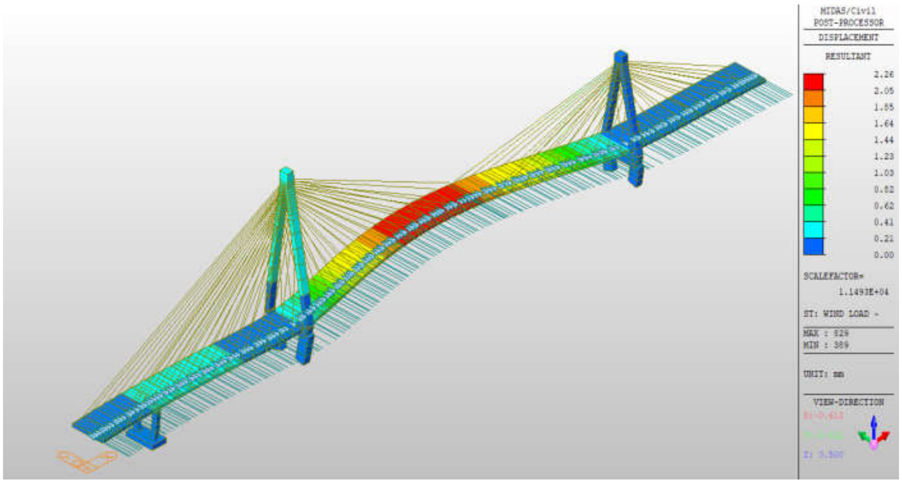

Figure 8. Deformation due to Transverse wind load

3.6.2 Result of Wind Analysis on Single Tied Arch Bridge:

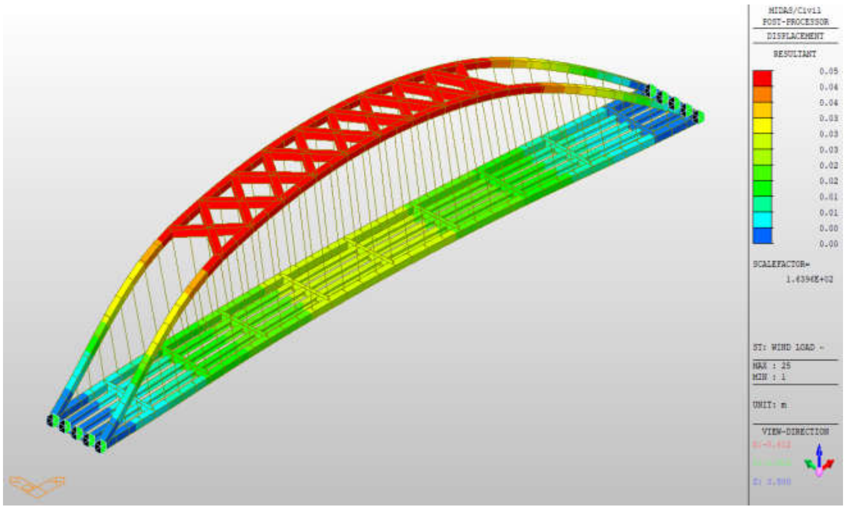

Figure 9. Deformations due to Transverse wind load

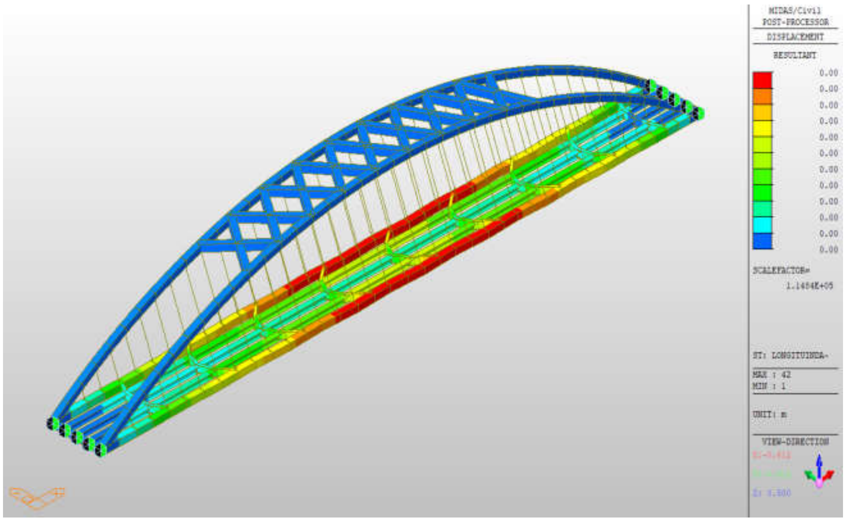

Figure 10.Deformation due Longitudinal Wind Force

4. CONCLUSION

1. In Cable Stayed bridge the effect of wind is more on the deck resulting in deformation.
2. Cable Stayed Bridge being more flexible, the study of wind effects and wind analysis plays a major role in design.
3. Therefore, we can say that Cable Stayed Bridges are better for short to medium distances
4. A brief review of several literatures presented shows that the precise nature of excitation and vibration development due towind loads still stay to be precisely understood.
5. On the other hand, wind has a minimal effect on the deck of Single Tied Arch Bridge.
6. Deformations in the Tied Arch Bridge are seen on the top bracing and near the tie section.
7. Therefore, Single Tied Arch Bridge would be better choice for longer span but is expensive than Cable Stayed Bridge.

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