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PARAMETRIC STUDY OF CABLE STAYED BRIDGE USING DIFFERENT PYLON CONFIGUARTION

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Abstract - Cable stayed bridge are the most flexible bridge and getting popularity because of its economy for longer spans. Cable stayed bridges have good stability, optimum use of structural materials, aesthetic, low design and maintenance costs, and efficient structural characteristics. Therefore, this type of bridges are given preference for long span crossings compared to suspension bridges. A study is carried out to find the dynamic effect on different configuration of pylons of a cable stayed bridge. A pylon is inclined at 5°, 10°, 15°, 20°, 25° and 30° with vertical and horizontal axis both and compared with vertical pylon to study the dynamic response of bridge. The 3D bridge models are prepared on CSI BRIDGE software and bridge is analyzed seismically by Imperial Valley 1947, Earthquake. The bridge response in terms of Pylon, Girder and Cable axial force, moment and torsion is obtained. The study reveals that the different angle of the pylon has great influence in the seismic response of cable stayed bridge. We are getting minimum axial force at 10° in cable at main span, girder at main span and pylon.

Keywords: Pylon configuration, Canted pylon, Time History Analysis, CSI bridge, Seismic Response, Imperial valley

I. INTRODUCTION

Human's achievements in structural Engineering are most evident in the World's largest bridge spans. Today the suspension bridge reaches a free span of almost 2000m (Akashi-Kaikyo Bridge, Japan) while its cable-stayed counterpart can cross almost 1000m (Tatara Bridge, Japan, Normandie Bridge, France). Cable-Stayed bridges, in particular, have become very popular in the past decade in United States, Japan and Europe as well as one third-world countries. There is still place for lots of innovation in Cable-Stayed Bridge techniques and the increase in their span length occurring during this last decade of the twentieth century is remarkable[1].

Bridges are critical lifeline structure that need to be continue to be functional while not harm when associate degree earthquake to facilitate the rescue and alleviation operations would like of long span bridge has accumulated with boom of infrastructure. the need of unbelievable bridges of lengthy span is increasing after every passing day due to increase in population inhabiting and their desire[2], Construction of cable-stayed bridge is a complex process that affected by many parameters such as stiffness and weight of structure, temperature, cable force and so on[3]. Bridge structures are typically more vulnerable to extreme loading conditions than are buildings, because bridges have less structural redundancy when compared to buildings[4].

In the last few decades, the single pylon cable-stayed bridges has become the most popular types of the bridges in engineering practice due to their aesthetic view, excellent spanning capacity, being able to rapidly and easily constructed, and efficient utilization of structural materials[5].

With the development of the world economy and the increase of the traffic volume, the long-span and broad width bridges have got fast development in recent years[6]. Nowadays, the economic main cable-stayed span ranges between 100 m with one tower and 1,100 m with two towers. Some examples include (1) the Lerez Bridge (Troyano et al., 1998) with a single inclined tower; (2) the Safti link bridge (Brownjohn and Xia, 2000) characterized by a curved deck and a single offset pylon; and (3) twin curved deck bridges (Gentile et al., 2004) and twin deck curved footbridges[7].

Cable-stayed bridge is a highly statically indeterminate structure, its structural behavior and total cost are affected by the cable arrangement and stiffness distribution in the cables, main girder and pylon. Furthermore, the distribution of member forces, such as maximum and minimum bending moments and axial forces in the main girder and pylon, and cable tensions, can be controlled considerably by giving prestresses to cables[8].

The cable stayed bridges constructed in earthquake prone areas, must be designed to withstand the seismic action. Cable-stayed bridges present long vibration periods, due to the long spans and their flexibility, which theoretically makes them not sensitive to dynamic excitation. The dynamic behaviour of cable-stayed bridges has been extensively studied by several authors. Abdel-Ghaffar and Nazmy considered a three-dimensional model, including the geometrical nonlinearities, to study the dynamic behaviour of long-span cable-stayed bridges under seismic loading. The cases of synchronous and nonsynchronous support excitations were considered and the effects of the nondispersive travelling seismic wave on the bridge response were studied[9].

II. PROBLEM DESCRIPTION

Cable-stayed bridges with multiple stay cables are highly redundant structures. So CSI BRIDGE software is used as it is a powerful and versatile tool for analysis and design of structures based dynamic finite element analysis.

In this paper cable stayed bridge having 824m main span is modeled with 7 different pylon configuration i.e. Vertical pylon, 5^{o}, 10^{o}, 15^{o}, 20^{o}, 25^{o} and 30^{o} inclined pylon in both vertical and horizontal direction.

III. METHODOLOGY

To arrive the above objectives following stepwise methodology is adopted (Figure.4.1).

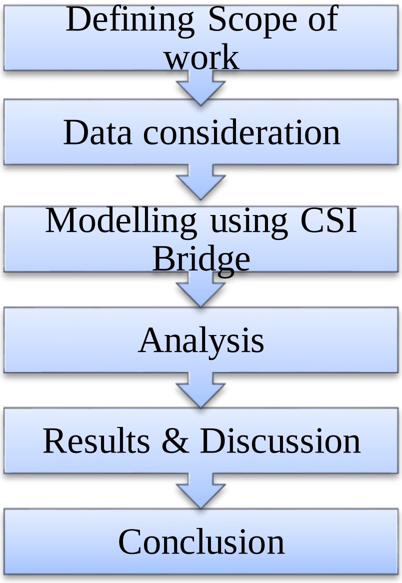


Figure 3.1 Flow chart methodology

IV. GEOMETRY OF BRIDGE

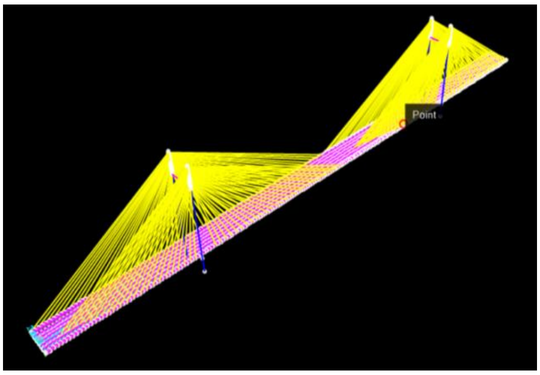
- Span Length = 824 m
- Main span length = 456 m
- Side spans length on both side = 184 m
- No of Cables = 200 no.
- Width of Bridge = 35 m
- Height of Pylon = 127 m
- Type of Cable Arrangement = Fan Type
- Shape of Pylon = H- shape

Table No. 1 Material Properties

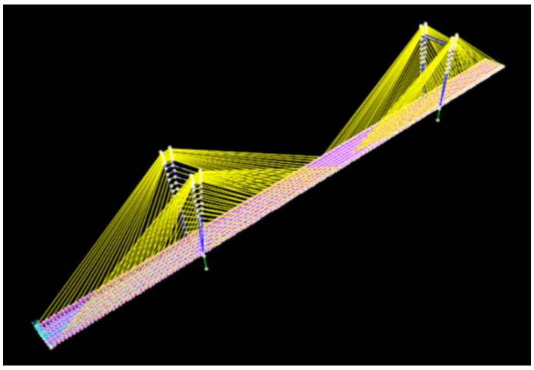
Material Name	Type	Grade	Elasticity (kN/m2)	Poisson Ratio
Girder	RCC	M60	38729833	0.2
Cable	Steel	Fe345	2.100E+08	0.3
Pylon	Steel	Fe345	2.100E+08	0.3
Pylon Transverse beam	Steel	Fe345	2.100E+08	0.3
Pylon-2	Steel	Fe345	2.100E+08	0.3

Table No. 2 Sectional Properties

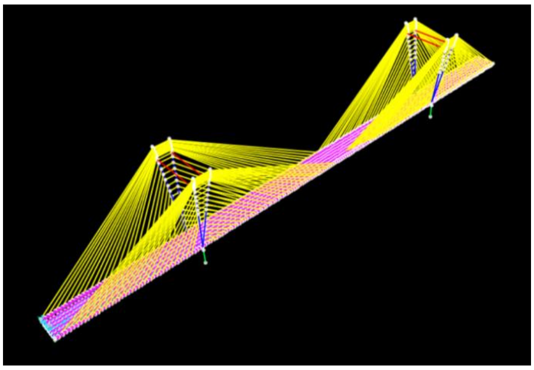
Section Name	Section Dimension Width(m) Height(m)	Type	Cross Sectional Area(m2)
Girder	0.3 3	RCC	0.9
Cable	0.3	Solid Circular	0.0707
PTB	4 4	Solid Rectangular	16
Pylon-2	3 3	Hollow Rectangular	4.08
Pylon	4 4	Hollow Rectangular	8.16



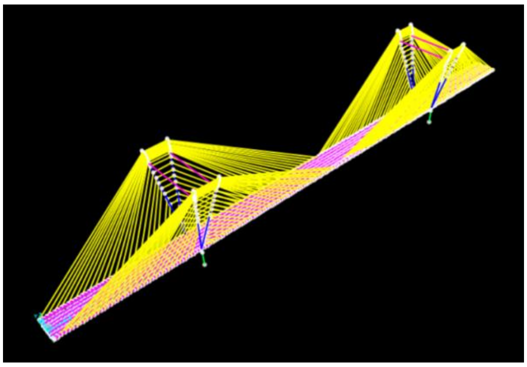
Model (1) - Vertical Pylon



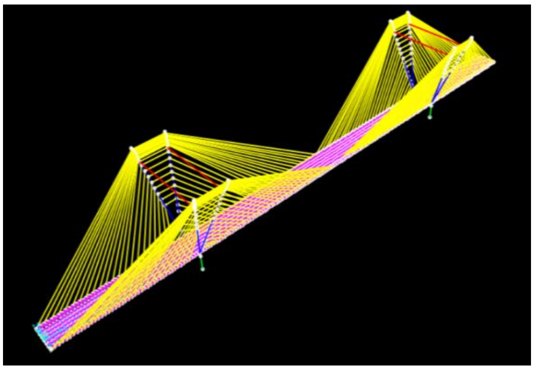
Model (2) - Pylon Inclined at 5º



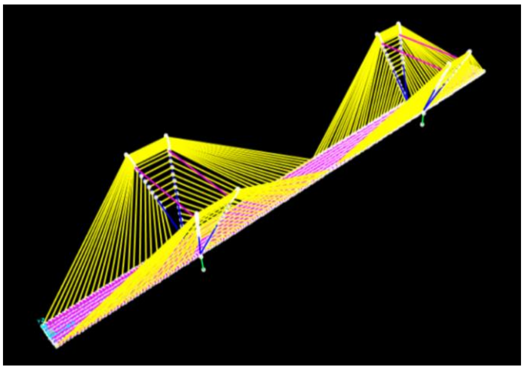
Model (3) – Pylon Inclined at 10º



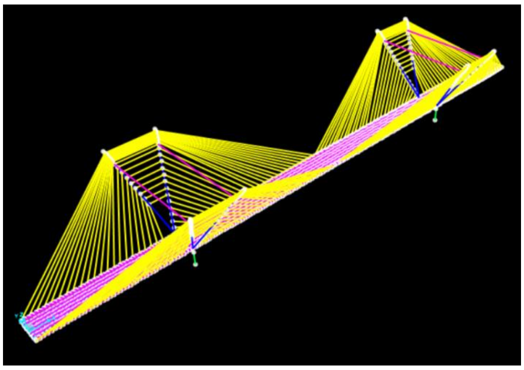
Model (4) – Pylon inclined at 15º



Model (5) – Pylon inclined at 20º



Model (6) – Pylon inclined at 25º



Model (7) – Pylon inclined at 30º

V. LOADS ACTING ON BRIDGE

1) SUPER IMPOSED DEAD LOAD

SIDL Loads like Barriers, Footpath and kerb taking as 0.5kN/m2

Asphalt Density = 22.00 kN/m3

Assume, Wearing Coat = 80mm

SIDL Load = 22 x 0.08 =1.76 kN/m2

Total SIDL Load = 1.76 + 0.5 = 2.26 kN/m2

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

2) Live Load

In this parametric study, moving loads on cable-stayed bridge are taken as per IRC- 6:2017 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) Wind Load

We had applied wind load according to IS: 875-2015(Part 3). Considering Zone wise data wind load is calculated and applied at velocity of 50 m/s.

VI. DEFINING PRESTRESS FORCE FOR THE CABLE

The initial Prestress force of a cable is calculated using the below empirical formula:

$F = \sigma \times A \times 60\%$
Where,
F is the initial prestress force,
σ is the yield stress of the cable and
A is the cross- sectional area of the cable

VII. THE BOUNDARY CONDITIONS

The boundary conditions of finite element model are always hard to model precisely the same as those of real structures. The approximate boundary conditions taken in this project.

The connection between the pier and the pylons has been considered as fixed connection. The connection between the cables and the bridge deck has been considered to be pinned as cable shouldn't take the rotational resistances.

VIII. TIME HISTORY ANALYSIS OF BRIDGE

To investigate the non- linear dynamic behavior of the bridge and to estimate the seismic behavior, 7 models with different pylon configuration is modeled based on time history analysis as per

Indian Codes. Imperial valley (1947) earthquake data is taken for dynamic analysis.

Table No 3: Detail of IMPERIAL VALLEY Earthquake

NAME	IMPERIAL VALLEY
MAGNITUDE	**6.95**
DURATION	**MEDIUM**
TIME OF ACCELRATION	**54 seconds**
TIME STEP	**0.01**

IX. RESULT AND DISCUSSION

A. Axial Force in Cable due to time history Analysis

Where, CMFP = Cable at main span far from pylon
CMNP = Cable at main span Near Pylon
CSFP = Cable at side span Far from pylon
CSFP = Cable at side span Near from pylon

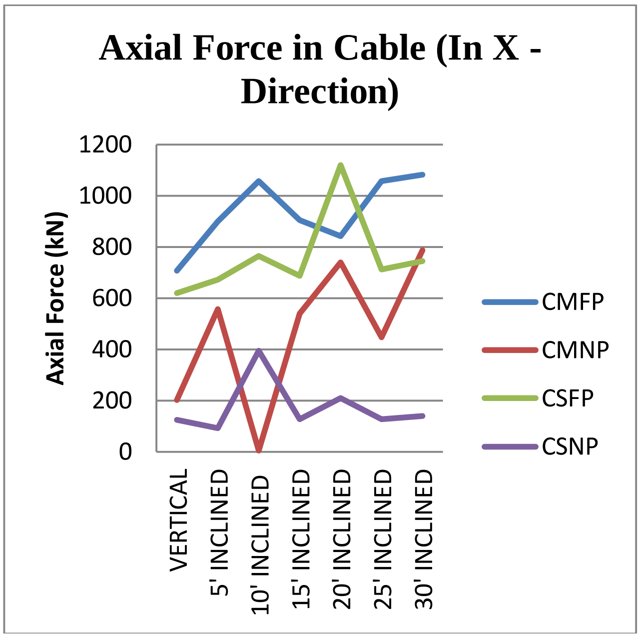


Chart 1. Axial Force in Cable X – direction

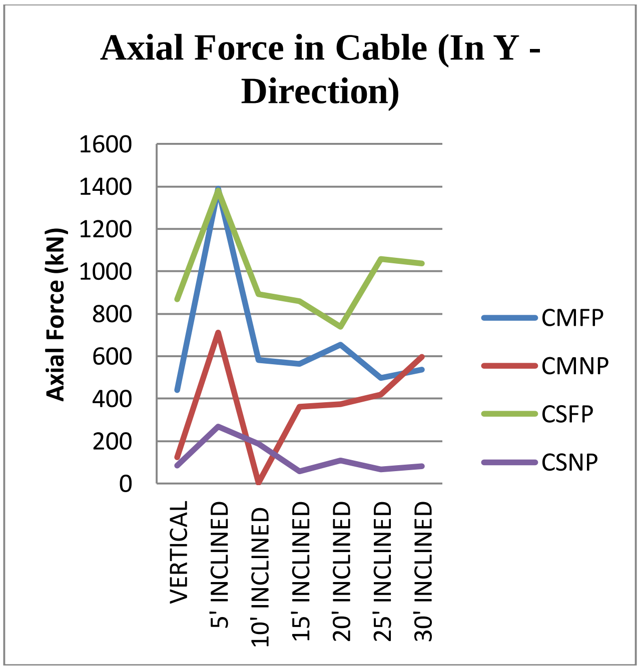


Chart 2. Axial Force in Cable Y - Direction

By observing the result from the graph, it can be analyzed that the minimum axial force we got in cable at vertical pylon configuration in X – direction and Y – Direction both at main span far from pylon while at 10° in cable near pylon.

B. Axial Force in Girder due to time history Analysis

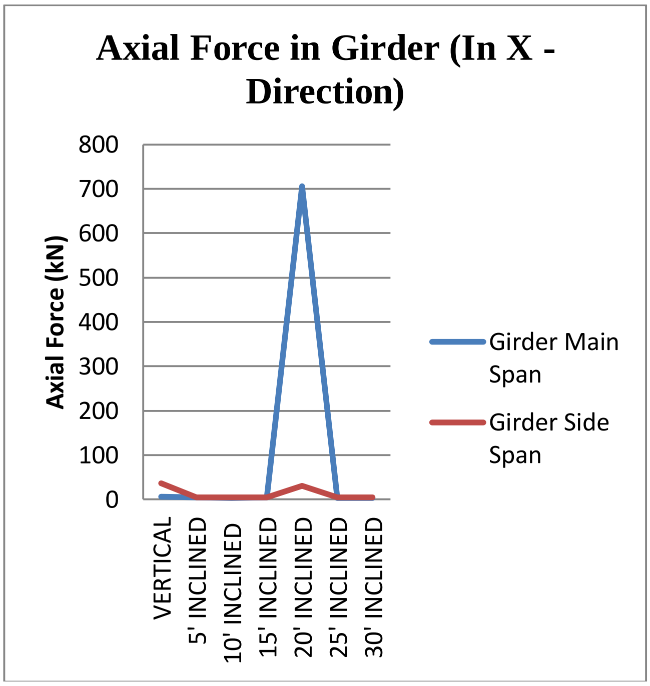


Chart 3. Axial Force in Girder X - Direction

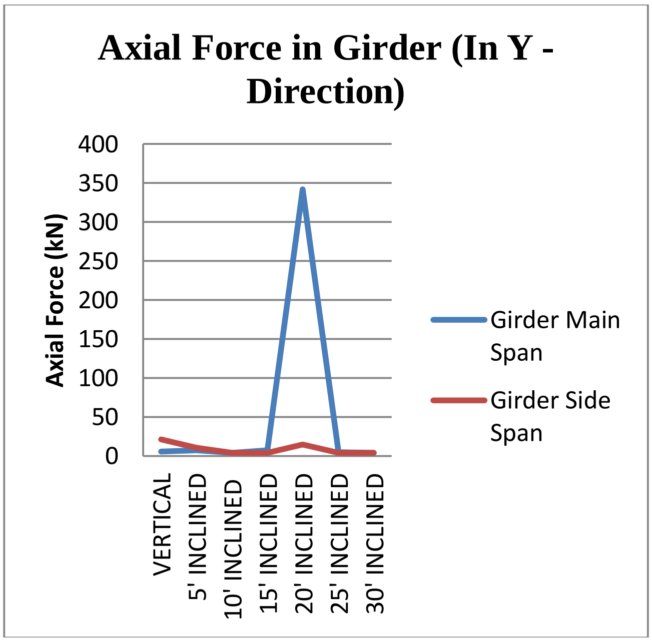


Chart 4. Axial Force in Girder Y – Direction

By observing the result from the graph, we can say that minimum axial force in girder we get at 10° angle at both main span and side span in X – Direction while at 30° in Y – Direction.

C. Axial Force in Pylon due to time history Analysis

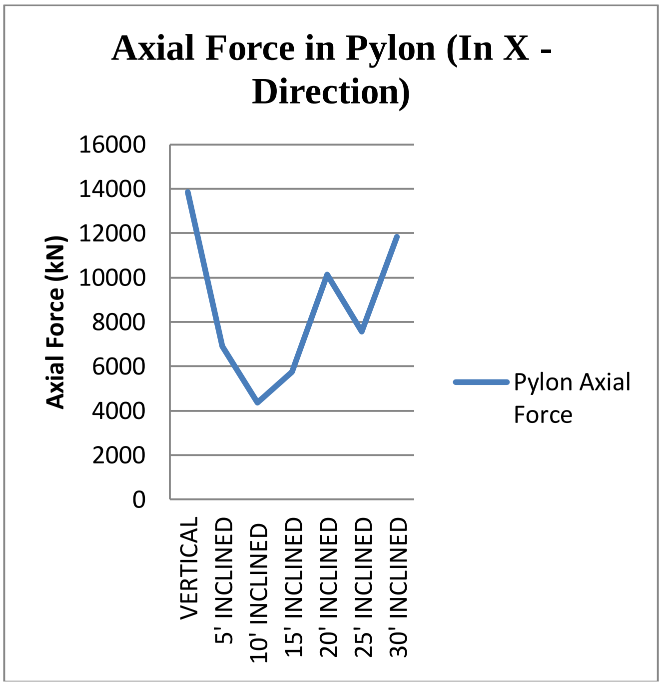


Chart 5. Axial Force in Pylon X- Direction

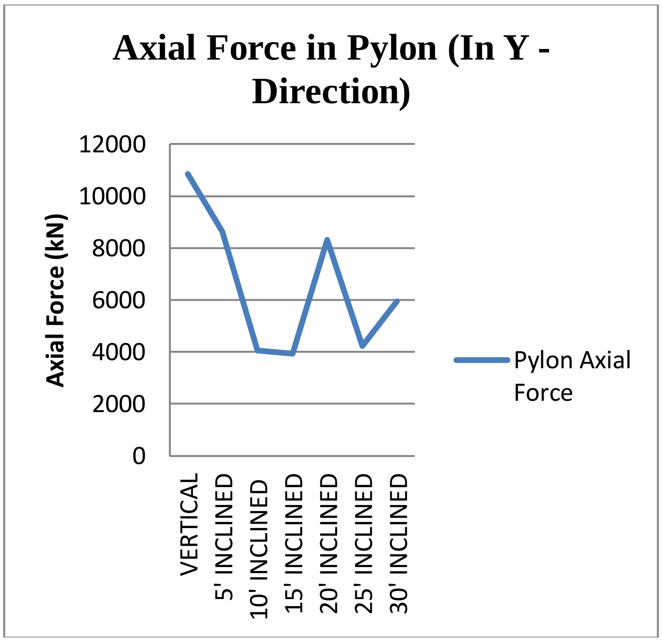


Chart 6. Axial Force in Pylon Y - Direction

By observing the graph we can say that, minimum axial force we got in pylon at 10° angle for X-Direction and at 15° angle for Y – Direction.

D. Moment in Pylon due to time history Analysis

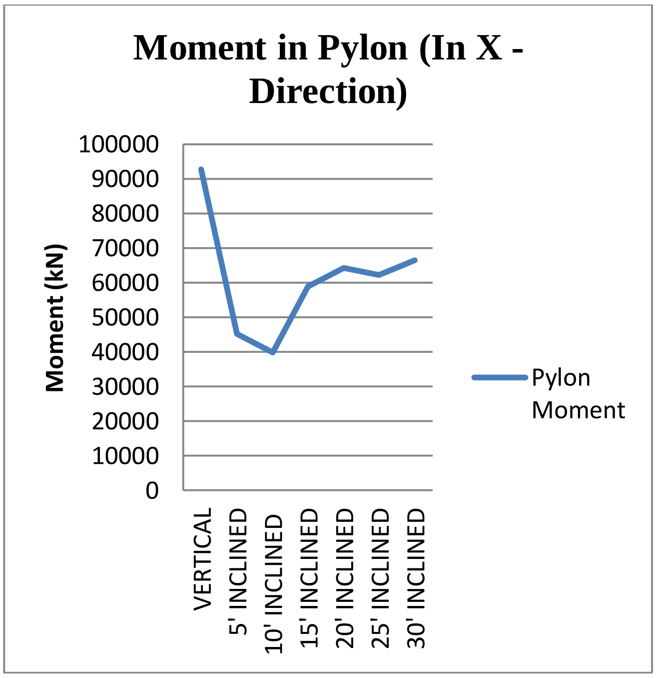


Chart 7. Moment in Pylon X – Direction

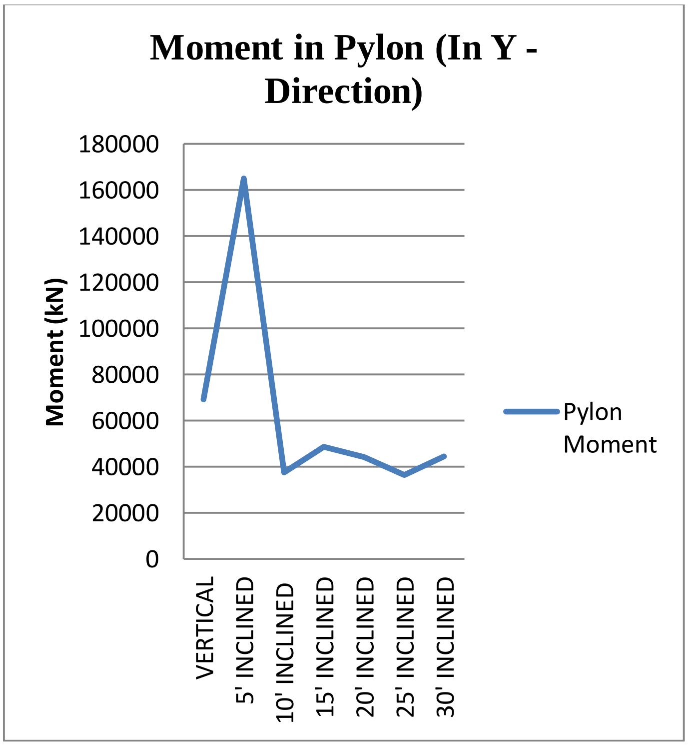


Chart 8. Moment in Pylon Y – Direction

From the above graph we can observed that, minimum moment we got in pylon at 10° angle for X- Direction and at 25° angle for Y – Direction.

E. Torsion in Pylon due to time history Analysis

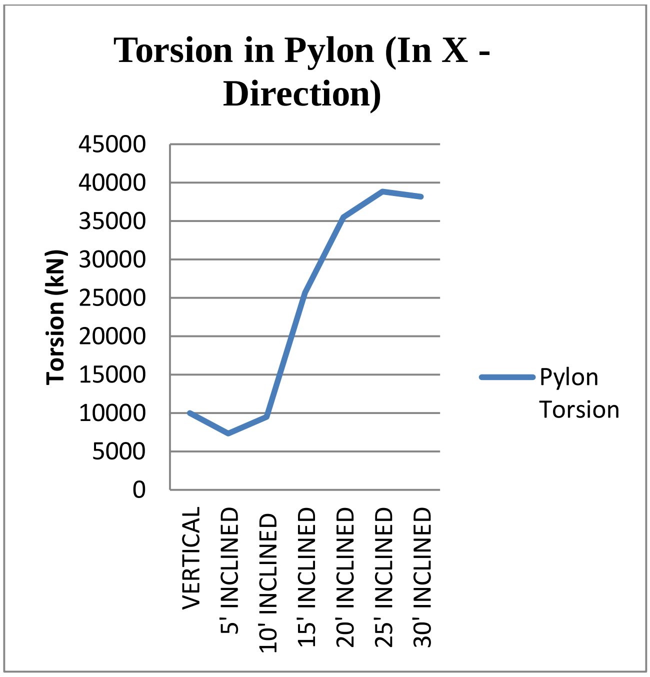


Chart 9. Torsion in Pylon X – Direction

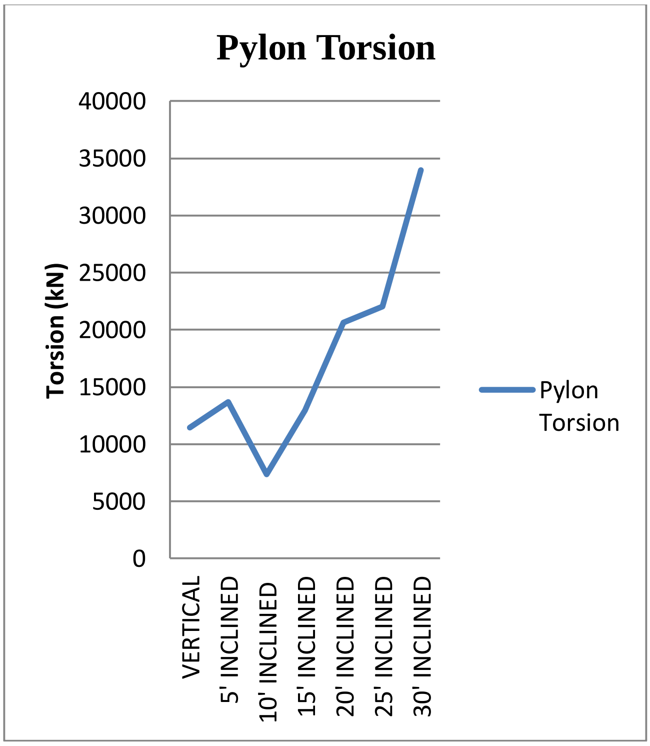


Chart 10. Torsion in Pylon Y – Direction

By observing the graph we can say that, minimum torsion we got in pylon at 5° angle for X- Direction and at 10° angle for Y – Direction.

X. CONCLUSION

From the analysis study, the following conclusions are drawn:

- We can conclude from research that minimum axial force we got at 10° in Cable at main span near pylon in X - Direction and Y - Direction both.
- Minimum axial force we got in girder at 10° at main span and side span both in X – Direction.
- Minimum axial force we got in pylon at 10° in X – Direction and at 15° for Y – Direction.
- Minimum moment in pylon we got at 10° and minimum torsion in pylon at 5°.

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