

Dynamic Performance of Nonlinear Cable-Stayed Bridges in Effect of Height and Inclination of Pylon

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Abstract- The design of a cable stayed bridge in an urban space requires particular consideration of aesthetics and environmental integration. Complex geometrical constraints, due to in-plan curved alignments, traffic maintenance requirements during erection stages and aspects related to the structural behavior and the competitiveness of cable-stayed solutions, are a challenge for designers. In aspect to that, this research work focusing on various parametric studies on investing the pylon and variable effect in nonlinear curved cable stayed bridge. In this study different height of pylon and inclined condition of pylon is going to study for cable-stayed bridge. To know behavior of cable stayed bridge when all parameters are staying constant except pylon height and inclination. Instead of straight pylon an inclined pylon is going to design. The bridge going to design is an asymmetric bridge. This change will affect the stiffness and may be improve the strength or adversely affect the strength. It should be analyzed using SAP 2000 software. Time history analysis is also going to carry out along with the dynamic properties. Earthquake ground motions are provided to the model and then time period, frequency, displacement, base shear on pylon, forces coming on the pylon and cables are to be studied.

Keywords: Curved cable stayed bridge, pylon height, inclination of pylon, Malpensa Airport bridge.

1. INTRODUCTION

The cable stayed bridges was introduced at the time that of the suspension bridge. 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 cost, 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 cable withstanding the weight of the deck. There are different types of pylons. i.e: H-type pylon, A type pylon, inverted Y type pylon, diamond shaped pylon etc.

Cable-stayed bridges have gained a lot of popularity in the last few decades, especially in developed countries, though this practice has raised, there are few parameters like wind loads, seismic loads, impact loads and other natural dynamic loads are still a concern to the structural designers, maintenance and construction community. A few of the primary reasons for the increase of cable-stayed bridges all over the world are their structural efficiency, aesthetic appeal, enhanced stiffness compared to suspension bridges, ease of construction, large spans and small size of substructures. Primarily it would be of highest advantage

were a large cantilever is needed for a span of the bridge and that point suspension bridge would be uneconomical.

1.1 OBJECTIVES

- To model and analysis a curved cable stayed bridge using SAP 2000.
- To understand the behaviour of a curved cable stayed bridge subjected to dynamic time history loads.
- To study the effect of inclination of pylon on response of mode shape of pylon.
- To study the effect of change in height of pylon on response of mode shapes

1.2 METHODOLOGY

The curved cable-stayed bridge is modelled with concrete structural elements. The models are further studied for different inclination and height of pylon. Malpensa Airport Bridge in Italy is taken as the reference. The software SAP2000 is used for modelling and analysis of the bridge. Time history analysis for different inclination and height of pylon is checked.

1.3 THEORATICAL INVESTIGATIONS

The concept of the cable-stayed bridges was first proposed in the seventeenth century. The cable-stayed bridges have many advantages than that of the suspension bridges. Govardhan Polepally et.al^[1] proposed the effect of the shape of the pylon on the seismic response of cable-stayed bridges. Priyanka Singh et.al^[2] also similarly studied about the shape of the pylon and their effects on the strength of the curved cable-stayed bridge. A cable stayed bridge comprises of pylons with cables withstanding the weight of the deck. H type A type, inverted Y type and diamond shaped pylons are studied by them and analyzing their shear force, bending moment and deflection. From the journal of Yogesh B Jankar et.al^[3] the dynamic time history analysis deck deflection is found to large in case of cable stayed bridge with large span. Pylon deflection is also found to be more in case of large span cable stayed bridge It is obtained from the journal of Carmelo Gentile et.al.^[4] Full scale tests were conducted to measure the dynamic response of the bridge, and two excitation techniques were considered: traffic induced ambient vibrations and free vibrations. Hongwei Cai, and Amjad J. Aref^[5] studied about the composite beam model of the curved cable stayed bridge. Eccentricity

has a larger influence on displacements and bending moments than on modal responses. All geometric nonlinearities are considered. **C. Gentile and F. Martinez y Cabrera (2004)** [6] published a journal which was the continuation of the journal proposed by Carmelo Gentile et.al. Here also, we can obtain the dimensional details of the Malpensa Airport bridge..Updating some uncertain structural parameters of the models, such as the Young's modulus of the concrete, in order to enhance the match between theoretical and experimental modal parameters.[6]. This bridge was studied by **James M.W. Brownjohn et.al.** [7] Long-span curved cable-stayed bridge with a single canted tower was studied by **Abolhassan Astaneh and R. Gary Black** [8]. Behavior of the curved cable-stayed structure under gravity, wind, earthquake and the combined effects of these loads are stable and desirable.[8]. This was proposed by **G. E. Valdebenito et.al.** [9] To reduce both internal forces and displacements, the harp pattern seems to be an efficient solution. **Alfredo Camara et.al.** [10] proposed about the push over analysis. This paper begins with a discussion of the advantages of a new non-linear static "Pushover" procedure that includes the three-dimensional contribution of the governing vibration modes [9].

2. MODEL OF MALPENSA AIRPORT BRIDGE.

The access to the air terminal of the Malpensa 2000 airport includes two curved cable-stayed bridges on the north and south of the terminal. The two bridges curve with a radius of 100m and a longitudinal slope of 6% so that the terminal seems to be embraced by the bridges that provide a limit to the airport area. Architectural concerns played a determining role in the design. Construction of the bridges was completed in 1997. Each bridge consists of an A shaped concrete tower, double plane cables and a concrete-girder bridge deck. The two side spans are symmetrical and the total center line length is 140m with four cables supporting each side span. The bridge deck has a width of 11.75m for two traffic lanes and two pedestrian lanes. The deck has a depth of 1.35m corresponding to about 1/100 of the total length. Thus, a rather flexible superstructure was designed, and a good transparency of the deck was attained from an aesthetic stand- point. The bridge deck consists of a five-cell concrete box girder which was cast in place and post-tensioned. The cast-in-place concrete tower is 36.87m high and consists of two concrete legs, a lower concrete cross-beam supporting the deck and an upper steel strut providing the anchorage for the stay cables. The stay cables are composed of strands having from 33 to 91 parallel wires, each 15.7mm in diameter. The shorter stays (33 wires) are 27m long, while the length of the longer ones (79 wires) is 47m [3]. Material properties of the bridge are given below.

Table 2.1: Material properties of the bridge.

DEFINITION	VALUE
The modulus of elasticity of the deck	$3.8 \times 10^8 \text{ KN/m}^2$
the modulus of elasticity of the cable.	$2.1 \times 10^8 \text{ KN/m}^2$
Effective tensile stress of cable	$4.9 \times 10^5 \text{ KN/m}^2$
Weight per unit length of the cable	76.972 KN/m^2
Modulus of elasticity of the concrete.	$3.8 \times 10^7 \text{ KN/m}^2$

Table 2.2: Model information.

SL.NO	PARAMETERS	
1	Type of stay cables	Parallel wires
2	Radius of the curve.	100m
3	Longitudinal slope	6%
4	Height of pylon	36.87m
5	Type of cable arrangement	A shaped
6	Main span	70m
7	Total length	140m
8	Deck width	11.75m
9	Number of lanes	2 traffic and 2 pedestrian
10	Number of curved cable stayed bridges.	2

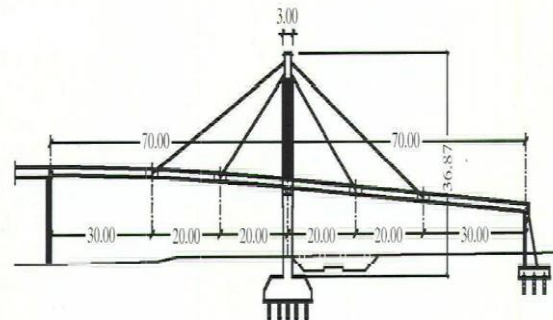


Figure 2.1: Elevation of Malpensa Airport Bridge.

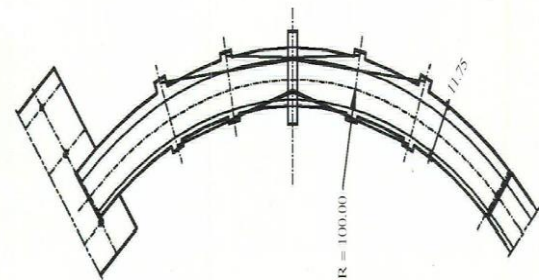


Figure 2.2: Plan of Malpensa Airport Bridge.

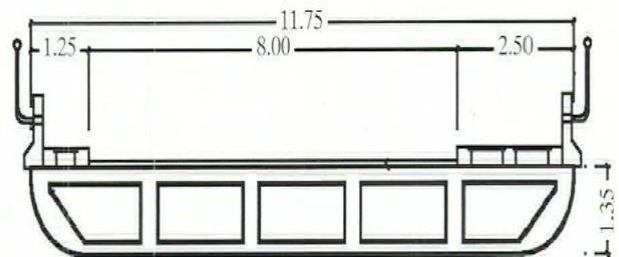


Figure 2.3: Deck Cross Section of Malpensa Airport Bridge.



Figure 2.4 Malpensa Airport Bridge.

The deck is modelled in SAP2000. After that frame properties of deck, cross girders, pylon, long cables and short cables are provided. Rectangular section is taken for the cross girder with width 3.5m and depth 1m. pylon is also rectangular section with width and depth 2m and 3m respectively. After assigning the frame properties section properties are assigned. Then support conditions are provided by using fully restrained condition. After that earthquake loads are provided. El Centro earthquake is taken into consideration.

2.1. El Centro earthquake.

El Centro earthquake was one of the devastating earthquakes in 1940 and affected the USA and Mexico. The north-south-component ground motion is considered and applied to the structure. Table 5.1 and 5.2 shows the deflection of deck slabs in longitudinal and transverse direction. C0, C1, C2, C3, C4, C5 and C6 are different points on the deck slab respectively.[1]

Table .2.3 Deflection of span in Longitudinal direction.

DECK	U1	U2	U3
C0	0	0	0
C1	-0.00421	-0.00141	-0.0136
C2	-0.00842	-0.00196	-0.00918
C2	-0.01186	-0.00139	-0.00188
C4	-0.0094	-0.0016	-0.0095
C5	-0.00428	-0.00232	-0.01535
C6	0	0	0

Table 2.4 Deflection of span in Transverse direction.

DECK	U1	U2	U3
C0	0	0	0
C1	-0.00864	-0.00583	-0.01944
C2	-0.00959	-0.00694	-0.01335
C2	-0.00253	-0.00683	-0.00098
C4	-0.00665	-0.00799	-0.01438
C5	-0.00897	-0.00839	-0.02395
C6	0	0	0

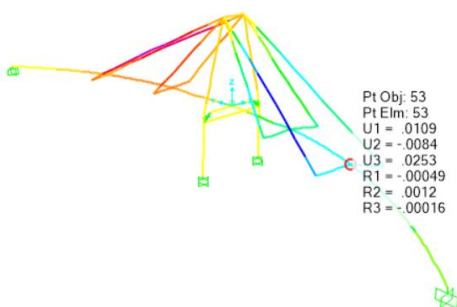


Figure 2.4. Deflection of deck slab in Longitudinal direction.

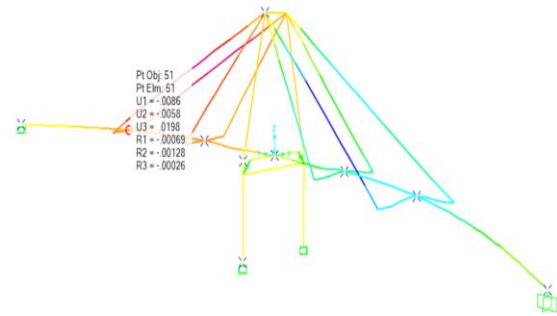


Figure 2.5. Deflection of deck slab in Transverse direction.

3. ANALYSIS WITH DIFFERENT TYPES OF INCLINATION.

3.1 ANALYSIS WITH 0° INCLINATION.

In this analysis the inclination of pylon is not changed. It is kept as 0° inclination with vertical axis. This is the inclination which is already provided on the curved cable stayed bridge. Time period of the curved cable stayed bridge during 0° inclination is calculated and is given in table 6.1.1

Table 3.1 Time period of bridge with 0° inclination

TIME PERIOD	MODAL		
	MODE 1	MODE 2	MODE 3
	0.715	2.008	2.656



Figure 3.1 Deck slab with 0° inclination.

The deck slab is divided into different points such as C0, C1, C2, C3, C4, C5 and C6. Then deflection caused at the deck slab due to 0° inclination in longitudinal direction was found out. The effect of deflection in deck span due to 0° inclination can be seen on U_x, U_y and U_z direction. Similarly, deflection caused at the deck slab due to 0° inclination at transverse direction is also found out. Here also when deflection is provided on the transverse direction effect of inclination can be seen on U_x, U_y and U_z direction.

The pylon is divided into three different points such as top, bottom and middle. The deflection caused at the pylon height due to 0° inclination at longitudinal direction as well as transverse direction is calculated. Here also effect of inclination

in longitudinal and transverse direction can seen on U_x , U_y and U_z direction. Similarly it is done for 5° , 10° , 15° and 20° .

Table 3.2 Deflection of deck slab in longitudinal direction.
(0°)

DECK	U1	U2	U3
C0	0	0	0
C1	-0.00421	-0.00141	-0.0136
C2	-0.00842	-0.00196	-0.00918
C3	-0.01186	-0.00139	-0.00188
C4	-0.0094	-0.0016	0.0095
C5	-0.00428	-0.00232	-0.01535
C6	0	0	0

Table 3.3 Deflection of deck slab in Transverse direction.
(0°)

DECK	U1	U2	U3
C0	0	0	0
C1	-0.00864	-0.00583	-0.01944
C2	-0.00959	-0.00694	-0.01335
C3	-0.00253	-0.00683	-0.00098
C4	-0.00665	-0.00799	-0.01438
C5	-0.00897	-0.00839	-0.02395
C6	0	0	0

Table 3.4 Deflection of pylon in longitudinal direction. (0°)

PYLON	U1	U2	U3
BOTTOM	0	0	0
MIDDLE	-0.01217	-0.00225	-0.00077
TOP	-0.02433	-0.00346	-0.0025

Table 3.5 Deflection of pylon in Transverse direction. (0°)

PYLON	U1	U2	U3
BOTTOM	0	0	0
MIDDLE	-0.00254	-0.01063	-0.00014
TOP	-0.00498	-0.02034	-0.00041

3.2 ANALYSIS WITH 5° INCLINATION.

In this analysis the inclination of pylon is changed as 5° with the vertical axis of curved cable stayed bridge. Time period of the curved cable stayed bridge during 5° inclination is calculated is given in table 6.2.1

Table 3.6 Time period of bridge with 5° inclination.

MODAL	TIME PERIOD		
	MODE1	MODE 2	MODE 3
	0.682	1.087	1.427

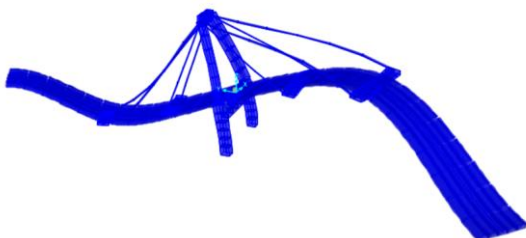


Figure 3.6 Deck slab with 5° inclination.

Table 3.7 Deflection of deck slab in longitudinal direction.
(5°)

DECK	U1	U2	U3
C0	0	0	0
C1	-0.00381	-0.00087	-0.02753
C2	-0.01234	-0.0013	-0.01416
C3	-0.01786	-0.00108	-0.01169
C4	-0.01414	-0.00185	-0.01024
C5	-0.00669	-0.00269	-0.02713
C6	0	0	0

Table 3.8 Deflection of deck slab in transverse direction.
(5°)

DECK	U1	U2	U3
C0	0	0	0
C1	-0.00929	-0.00654	-0.01893
C2	-0.01115	-0.00779	-0.01498
C3	-0.0026	-0.00755	-0.00746
C4	-0.0084	-0.00889	-0.01712
C5	-0.01178	-0.00939	-0.0236
C6	0	0	0

Table 3.9 Deflection of Pylon height in longitudinal direction. (5°)

PYLON	U1	U2	U3
BOTTOM	0	0	0
MIDDLE	-0.02194	-0.00139	-0.00059
TOP	-0.03135	-0.00423	-0.00293

Table 3.10 Deflection of Pylon height in longitudinal direction. (5°)

PYLON	U1	U2	U3
BOTTOM	0	0	0
MIDDLE	-0.00286	-0.00704	-0.0005
TOP	-0.00694	-0.01538	-0.00141

3.3 ANALYSIS WITH 10° INCLINATION

In this analysis the inclination of pylon is changed as 10° with the vertical axis of curved cable stayed bridge. Time period of the curved cable stayed bridge during 5° inclination is calculated is given in table 6.3.1

Table 3.11 Time Period of bridge with 10° inclination

MODAL	TIME PERIOD		
	MODE 1	MODE 2	MODE 3
	0.737	1.94	2.56

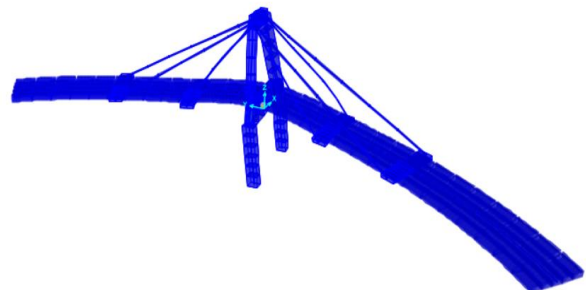


Figure 3.10 Deck slab with 10° inclination.

Table 3.12 Deflection of Deck span in longitudinal direction (10^0)

DECK	U1	U2	U3
C0	0	0	0
C1	-0.00533	-0.00212	-0.02141
C2	-0.0105	-0.00325	-0.01475
C3	-0.01418	-0.00267	-0.00206
C4	-0.01004	-0.00286	-0.01013
C5	-0.00441	-0.00416	-0.02336
C6	0	0	0

Table 3.13 Deflection of Deck span in Transverse direction (10^0)

DECK	U1	U2	U3
C0	0	0	0
C1	-0.00724	-0.00481	-0.02294
C2	-0.00856	-0.00578	-0.0159
C3	-0.00443	-0.0057	-0.00194
C4	-0.00659	-0.00678	-0.01799
C5	-0.00826	-0.0072	-0.02566
C6	0	0	0

Table 3.14 Deflection of Pylon height in longitudinal direction (10^0)

PYLON	U1	U2	U3
BOTTOM	0	0	0
MIDDLE	-0.01457	-0.00301	-0.00078
TOP	-0.02735	-0.00495	-0.00319

Table 3.15 Deflection of Pylon height in Transverse direction (10^0)

PYLON	U1	U2	U3
BOTTOM	0	0	0
MIDDLE	-0.00453	-0.00819	-0.00132
TOP	-0.00716	-0.01675	-0.00268

3.4 ANALYSIS WITH 15^0 INCLINATION

In this analysis the inclination of pylon is changed as 15^0 with the vertical axis of curved cable stayed bridge. Time period of the curved cable stayed bridge during 5^0 inclination is calculated is given in table 6.4.1

Table 3.16 Time period of bridge with 15^0 inclination

MODAL	TIME PERIOD		
	MODE 1	MODE 2	MODE 3
	0.742	1.914	2.543



Figure 3.15 Deck slab with 15^0 inclination.

Table 3.16 Deflection of deck span in longitudinal direction (15^0)

DECK	U1	U2	U3
C0	0	0	0
C1	-0.00593	-0.00255	-0.02186
C2	-0.01099	-0.00377	-0.01486
C3	-0.01445	-0.00317	-0.00231
C4	-0.00955	-0.00323	-0.01165
C5	-0.00495	-0.00465	-0.02341
C6	0	0	0

Table 3.17 Deflection of deck span in Transverse direction (15^0)

DECK	U1	U2	U3
C0	0	0	0
C1	-0.00674	-0.00448	-0.0248
C2	-0.00807	-0.00547	-0.01697
C3	-0.00506	-0.00526	-0.00236
C4	-0.00633	-0.00637	-0.01922
C5	-0.0079	-0.00694	-0.02759
C6	0	0	0

Table 3.18 Deflection of Pylon height in longitudinal direction (15^0)

PYLON	U1	U2	U3
BOTTOM	0	0	0
MIDDLE	-0.015	-0.00358	-0.00116
TOP	-0.02955	-0.0058	-0.00335

Table 3.19 Deflection of Pylon height in Transverse direction (15^0)

PYLON	U1	U2	U3
BOTTOM	0	0	0
MIDDLE	-0.00516	-0.00781	-0.00193
TOP	-0.00833	-0.01557	-0.0043

3.5 ANALYSIS WITH 20^0 INCLINATION

In this analysis the inclination of pylon is changed as 20^0 with the vertical axis of curved cable stayed bridge. Time period of the curved cable stayed bridge during 5^0 inclination is calculated is given in table 6.5.1

Table 3.20 Time period of bridge with 20^0 inclination

MODAL	TIME PERIOD		
	MODE 1	MODE 2	MODE 3
	0.746	1.872	2.517

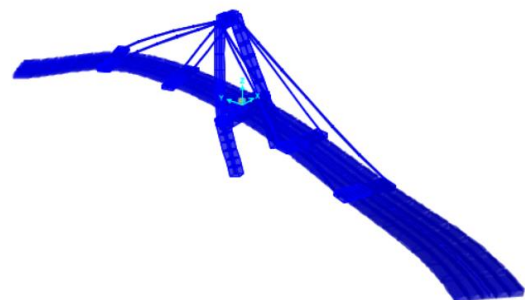


Figure 3.21 Deck slab with 20^0 inclination.

Table 3.21 Deflection of deck span in longitudinal direction (20^0)

DECK	U1	U2	U3
C0	0	0	0
C1	-0.00643	-0.00291	-0.02065
C2	-0.01164	-0.00423	-0.01398
C3	-0.01489	-0.00362	-0.00237
C4	-0.00941	-0.0037	-0.01105
C5	-0.00529	-0.00522	-0.02201
C6	0	0	0

Table 3.22 Deflection of deck span in Transverse direction (20^0)

DECK	U1	U2	U3
C0	0	0	0
C1	-0.00622	-0.00415	-0.02511
C2	-0.00736	-0.00504	-0.01696
C3	-0.00567	-0.00493	-0.00241
C4	-0.00603	-0.00614	-0.0192
C5	-0.00748	-0.0067	-0.0293
C6	0	0	0

Table 3.22 Deflection of Pylon height in longitudinal direction (20^0)

PYLON	U1	U2	U3
BOTTOM	0	0	0
MIDDLE	-0.01541	-0.00415	-0.0014
TOP	-0.03022	-0.0071	-0.00369

Table 3.23 Deflection of Pylon height in Transverse direction (20^0)

PYLON	U1	U2	U3
BOTTOM	0	0	0
MIDDLE	-0.0058	-0.00712	-0.00233
TOP	-0.01008	-0.01442	-0.0061

3.6 RESULTS AND DISCUSSION

Deck span Vs deflection graph of 0^0 , 5^0 , 15^0 and 20^0 are taken. Time history analysis of deck span in longitudinal and transverse direction are taken. Changes are found out in X,Y and Z direction in case of both longitudinal and transverse direction. Similarly Time history analysis of pylon height also taken and compared in longitudinal and transverse direction.

Table 6.6 Comparison of Time period.

MODAL	TIME PERIOD		
	MODE 1	MODE 2	MODE 3
0 DEG	0.715	2.008	2.656
5 DEG	0.682	1.087	1.427
10 DEG	0.737	1.949	2.569
15 DEG	0.742	1.914	2.543
20 DEG	0.746	1.872	2.517

3.6.1 Time history analysis in longitudinal direction.

Comparing the deflection of deck slab in longitudinal direction at different inclinations graph at X, Y and Z direction are drawn. The deflection of pylon height at top, bottom and middle at different inclinations are compared and drawn.

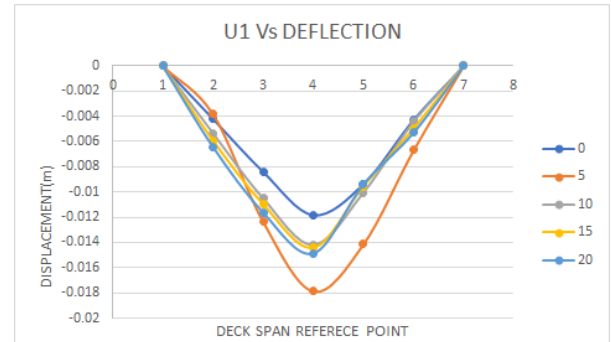


Figure 3.26 Time history analysis of deck in longitudinal direction.(U1)

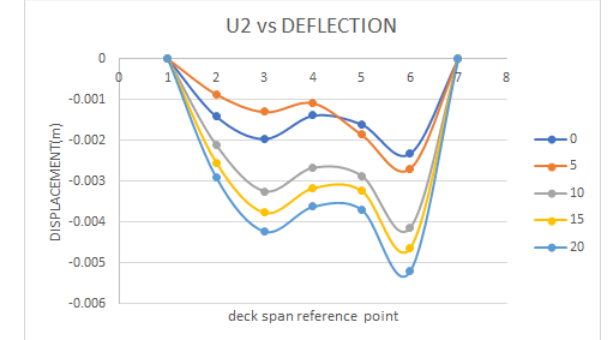


Figure 3.27 Time history analysis of deck in longitudinal direction.(U2)

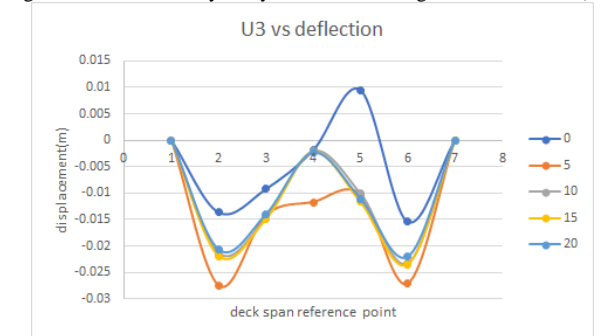


Figure 3.28 Time history analysis of deck in longitudinal direction.(U3)

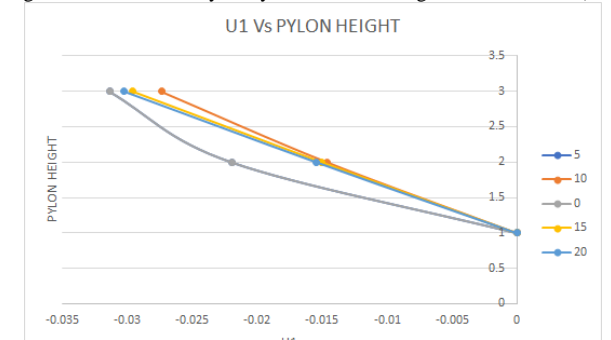


Figure 3.29 Time history analysis of Pylon in longitudinal direction (U1)

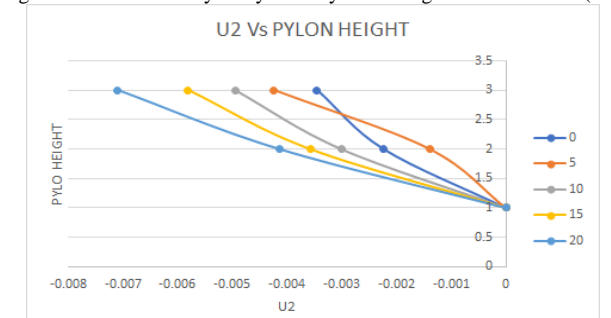


Figure 3.28 Time history analysis of Pylon in longitudinal direction (U2)

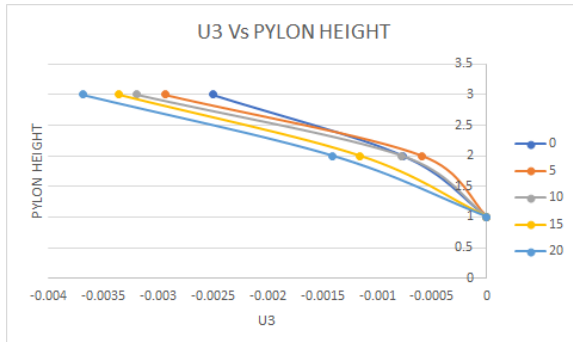


Figure 3.29 Time history analysis of Pylon in longitudinal direction (U3)

3.6.2 Time history analysis in transverse direction.

Comparing the deflection of deck slab in transverse direction at different inclinations graph at X, Y and Z direction are drawn. The deflection of pylon height at top, bottom and middle at different inclinations are compared and drawn.

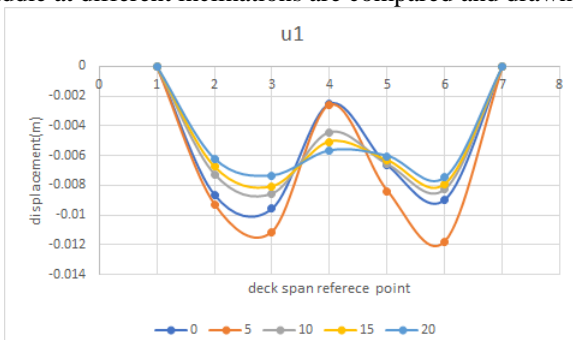


Figure 3.30 Time history analysis of deck in transverse direction.(U1)

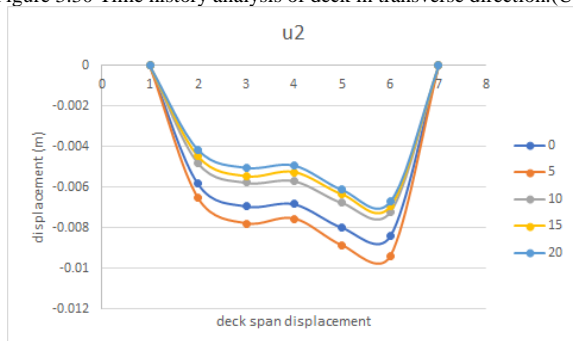


Figure 3.31 Time history analysis of deck in transverse direction.(U2)

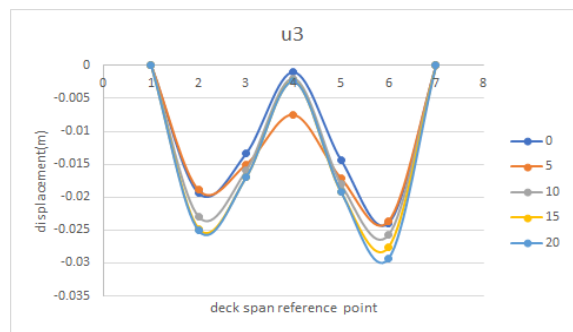


Figure 3.32 Time history analysis of deck in transverse direction.(U3)

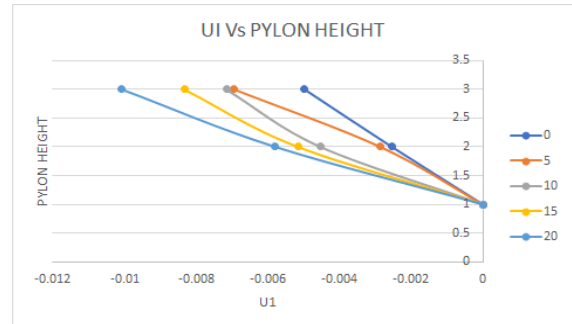


Figure 3.33 Time history analysis of deck in transverse direction. (U1)

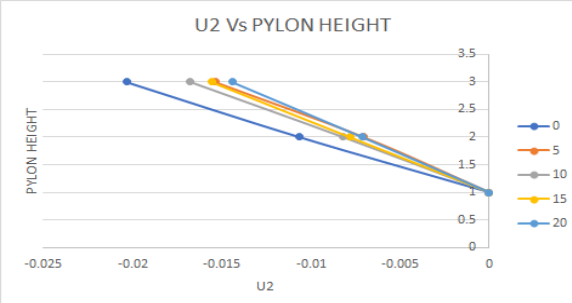


Figure 3.34 Time history analysis of deck in transverse direction.(U2)

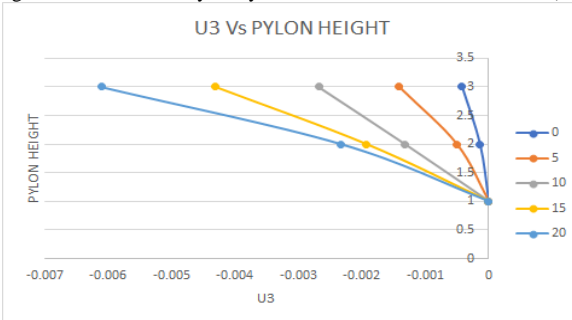


Figure 3.35 Time history analysis of deck in longitudinal direction.(U3)

In the case of deflection analysis 5° inclination shows less time period. Hence stiffness is more for 5° inclination and displacement is less. Comparatively less deflection can be seen on 5° inclination. In the case of transverse deflection good performance is obtained at 20° inclination. But compared with other results 5° has lesser time period. Mid displacement is controlled in transverse direction also. It can be concluded that 5° is the most accurate inclination over other inclinations.

4. ANALYSIS WITH THE CHANGE IN PYLON HEIGHT

4.1 PYLON HEIGHT

The height of the pylon is varied in this session. From the first analysis it is understood that in terms of time history analysis and deflection of deck slab and pylon, 5° inclination gives the best result. Therefore, height of the pylon is changing in 5° only. The pylon height of Malpensa Airport bridge is 36.87m. this height is increased to 39.87m and 33.87m.

The deflection of deck span and pylon height of 5° in case of 36.87m is same as that of 50 obtained in the first analysis.

4.2 NORMAL PYLON HEIGHT

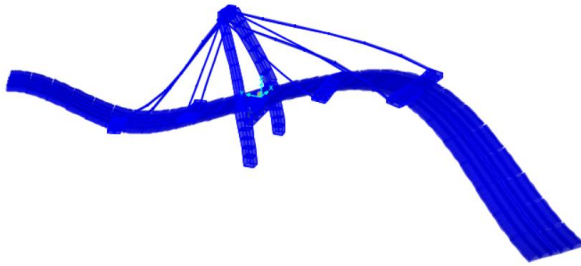


Figure 4.1 Bridge with 36.87m height and 5° inclination.

Table 4.1 Deflection of deck slab in longitudinal direction. (5°)

DECK	U1	U2	U3
C0	0	0	0
C1	-0.00381	-0.00087	-0.02753
C2	-0.01234	-0.0013	-0.01416
C3	-0.01786	-0.00108	-0.01169
C4	-0.01414	-0.00185	-0.01024
C5	-0.00669	-0.00269	-0.02713
C6	0	0	0

Table 4.2 Deflection of deck slab in transverse direction. (5°)

DECK	U1	U2	U3
C0	0	0	0
C1	-0.00929	-0.00654	-0.01893
C2	-0.01115	-0.00779	-0.01498
C3	-0.0026	-0.00755	-0.00746
C4	-0.0084	-0.00889	-0.01712
C5	-0.01178	-0.00939	-0.0236
C6	0	0	0

Table 4.2 Deflection of Pylon height in longitudinal direction. (5°)

PYLON	U1	U2	U3
BOTTOM	0	0	0
MIDDLE	-0.02194	-0.00139	-0.00059
TOP	-0.03135	-0.00423	-0.00293

Table 4.3 Deflection of Pylon height in longitudinal direction. (5°)

PYLON	U1	U2	U3
BOTTOM	0	0	0
MIDDLE	-0.00286	-0.00704	-0.0005
TOP	-0.00694	-0.01538	-0.00141

4.3 PYLON HEIGHT 3m+

The height of the pylon is varied to 39.87m. the inclination is kept as 5° itself.

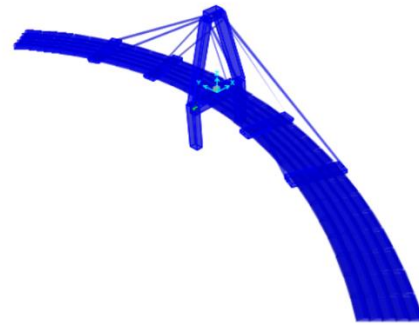


Figure 4.6 Bridge with 39.87m height and 5° inclination

Table 4.4 Deflection of deck slab in longitudinal direction. (5°)

DECK	U1	U2	U3
C0	0	0	0
C1	-0.00397	-0.0008	-0.02509
C2	-0.01248	-0.00112	-0.0135
C3	-0.01789	-0.00103	-0.01234
C4	-0.01425	-0.00176	-0.0099
C5	-0.00661	-0.00224	-0.02456
C6	0	0	0

Table 4.5 Deflection of deck slab in transverse direction. (5°)

DECK	U1	U2	U3
C0	0	0	0
C1	-0.00909	-0.00635	-0.02206
C2	-0.011	-0.00762	-0.01692
C3	-0.00251	-0.00738	-0.00785
C4	-0.00805	-0.00876	-0.02014
C5	-0.01138	-0.00925	-0.02595
C6	0	0	0

Table 4.6 Deflection of Pylon height in longitudinal direction. (5°)

PYLON	U1	U2	U3
BOTTOM	0	0	0
MIDDLE	-0.0254	-0.00216	-0.00073
TOP	-0.03528	-0.00443	-0.00269

Table 4.7 Deflection of Pylon height in transverse direction. (5°)

PYLON	U1	U2	U3
BOTTOM	0	0	0
MIDDLE	-0.00228	-0.00741	-0.00067
TOP	-0.00611	-0.01943	-0.00179

4.4 PYLON HEIGHT 3m-

The pylon height is varied to 33.87m. the inclination is kept as 5° itself.

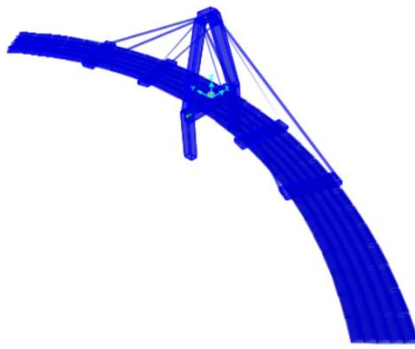


Figure 4.10 Bridge with 33.87m height and 5° inclination.

Table 4.8 Deflection of deck slab in longitudinal direction. (5°)

DECK	U1	U2	U3
C0	0	0	0
C1	-0.00397	-0.0008	-0.02509
C2	-0.01248	-0.00112	-0.0135
C3	-0.01789	-0.00103	-0.01234
C4	-0.01425	-0.00176	-0.0099
C5	-0.00661	-0.00224	-0.02456
C6	0	0	0

Table 4.9 Deflection of deck slab in longitudinal direction. (5°)

DECK	U1	U2	U3
C0	0	0	0
C1	-0.00909	-0.00635	-0.02206
C2	-0.011	-0.00762	-0.01692
C3	-0.00251	-0.00738	-0.00785
C4	-0.00805	-0.00876	-0.02014
C5	-0.01138	-0.00925	-0.02595
C6	0	0	0

Table 4.10 Deflection of Pylon height in longitudinal direction. (5°)

PYLON	U1	U2	U3
BOTTOM	0	0	0
MIDDLE	-0.0254	-0.00216	-0.00073
TOP	-0.03528	-0.00443	-0.00269

Table 4.11 Deflection of Pylon height in longitudinal direction. (5°)

PYLON	U1	U2	U3
BOTTOM	0	0	0
MIDDLE	-0.00228	-0.00741	-0.00067
TOP	-0.00611	-0.01943	-0.00179

4.5 RESULTS AND DISCUSSIONS

The height of the pylon is varied for 5° inclination only. The heights analyzed are 36.87m which is the original height of Malpensa Airport bridge, 39.87m which is 3m more from the original height and 33.87m which is 3m less from the original height. In this analysis also deflection in longitudinal direction for the deck slab and pylon height affects X, Y and Z directions. Deflection in transverse direction also analyzed and compared the results in X, Y and Z directions.

4.5.1 Time history analysis in longitudinal direction.

Comparing the deflection of deck slab in longitudinal direction at different inclinations graph at X, Y and Z

direction are drawn. The deflection of pylon height at top, bottom and middle at different inclinations are compared and drawn.

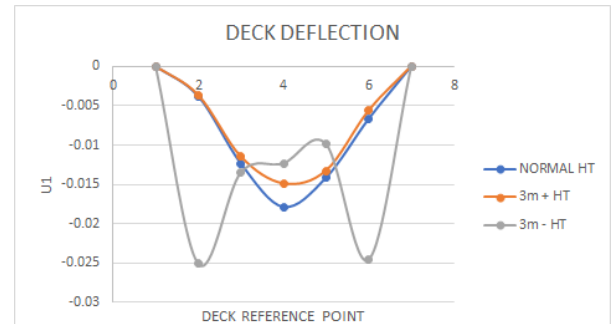


Figure 4.14 Time history analysis of deck in longitudinal direction.(U1)

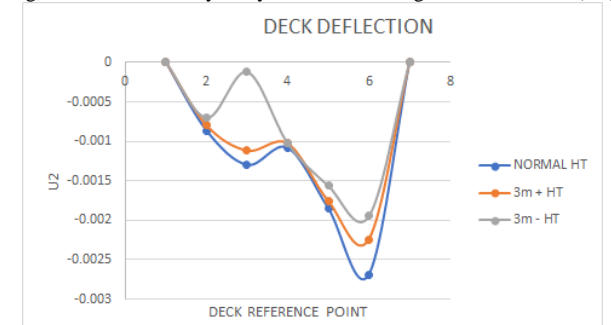


Figure 4.15 Time history analysis of deck in longitudinal direction.(U2)

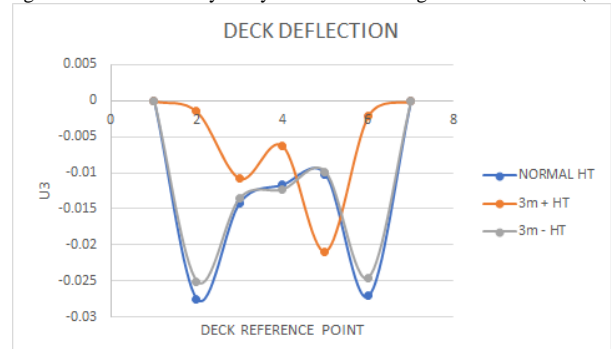


Figure 4.16 Time history analysis of deck in longitudinal direction.(U3)

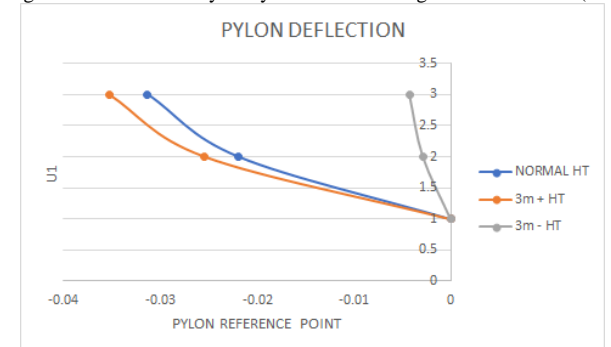


Figure 4.17 Time history analysis of Pylon in longitudinal direction.(U1)

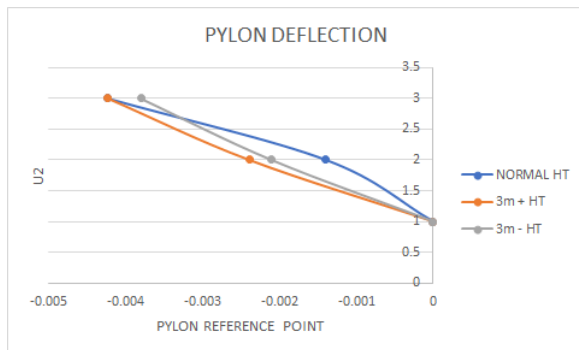


Figure 4.18 Time history analysis of Pylon in longitudinal direction.(U2)

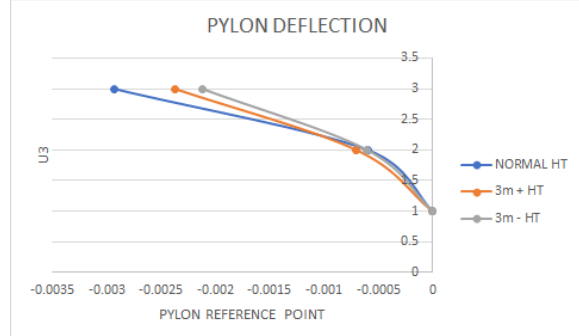


Figure 4.19 Time history analysis of Pylon in longitudinal direction.(U3)

4.5.2 Time history analysis in transverse direction.

Comparing the deflection of deck slab in transverse direction at different inclinations graph at X, Y and Z direction are drawn. The deflection of pylon height at top, bottom and middle at different inclinations are compared and drawn.

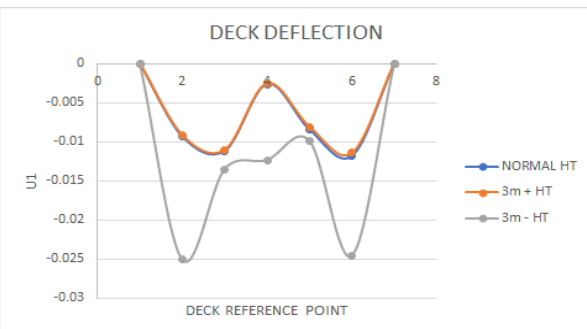


Figure 4.20 Time history analysis of deck in transverse direction.(U1)

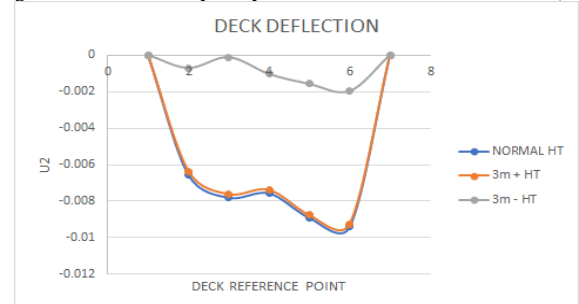


Figure 4.21 Time history analysis of deck in transverse direction.(U2)

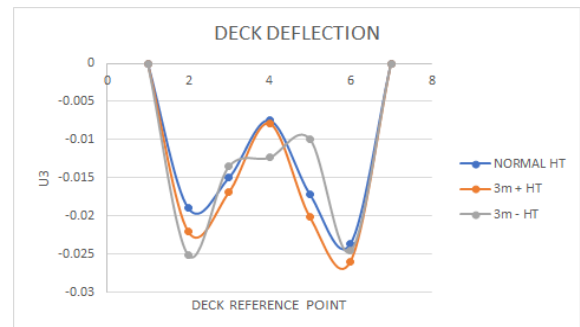


Figure 4.22 Time history analysis of deck in transverse direction.(U3)

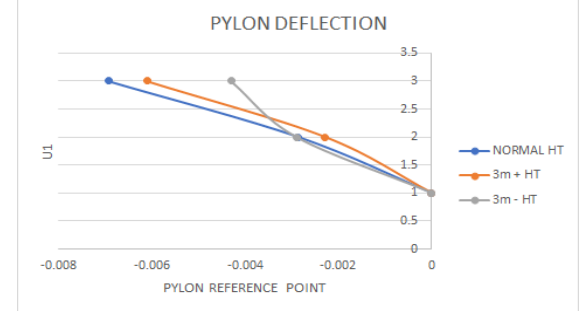


Figure 4.23 Time history analysis of pylon in transverse direction.(U1)

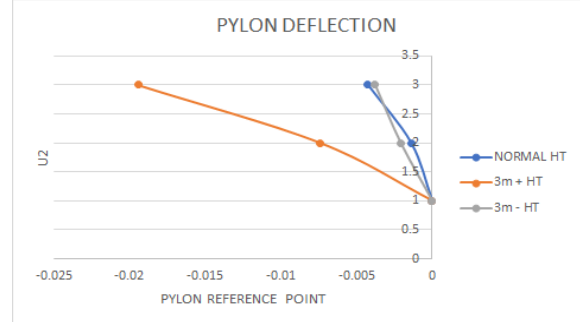


Figure 4.24 Time history analysis of pylon in transverse direction.(U2)

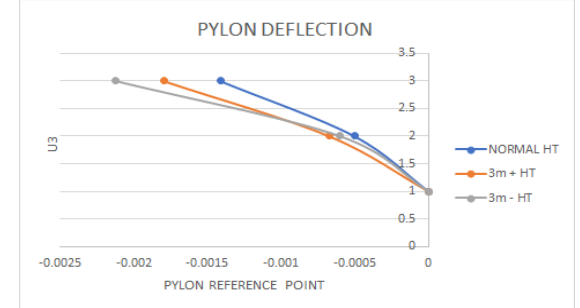


Figure 4.25 Time history analysis of pylon in transverse direction.(U3)

On comparing the time period behavior of deck slab and pylon on 5° inclination and varying height it is understood that as the height decreases stiffness is more and deflection is less. Hence it can be concluded that lesser pylon height of 33.87m is more safer than that of the normal height 36.87m of Malpensa Airport bridge. Time period is less hence oscillation is less. Performance is good when the height is decreased.

5. CONCLUSIONS

Cable stayed bridges are the most flexible bridges and getting popularity because of its economy for longer spans and aesthetics. Civil engineering projects always have a shortcoming of understanding through actual scaled

experimental models either due to their scale, cost or time taking process. So, largely numerical models play a vital role due to their ease in modelling, computations and faster parametric studies. In this study, design considerations for curved cable-stayed bridges under deflection and time history analysis are discussed. The numerical model of bridge was designed in SAP2000 software and earthquake ground motions are provided. The changes in the bridge in deflection and time history analysis when the inclination and height of the pylon is changed was discussed. the analysis was done in two parts.

- Inclinations provided are 0^0 , 5^0 , 15^0 and 20^0
- In the case of deflection analysis 5^0 inclination shows less time period.
- Hence stiffness is more for 5^0 inclination and displacement is less.
- Comparatively less deflection can be seen on 5^0 inclination.
- In the case of transverse deflection good performance is obtained at 20^0 inclination.
- It can be concluded that 5^0 is the most accurate inclination over other inclinations.
- Since in the case of deflection analysis 5^0 inclination gives the best result, only height of 5^0 inclination is varied.
- Actual height of the tower was 36.87m. It was reduced to 33.86m and 39.87m.
- Changes in longitudinal and transverse direction are found out and graph is drawn.
- It is observed that as the height decreases, deflection is less and more stiffness is obtained.
Height of 33.86m is more stiffer than that of original height of the bridge

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