How to Cite:
Vardhan, H., Patil, A. C. R., & Anushree, A. (2022). Static and dynamic analysis of a cable stayed bridges. *International Journal of Health Sciences*, *6*(S9), 3807–3826. Retrieved from https://sciencescholar.us/journal/index.php/ijhs/article/view/13485

Static and dynamic analysis of a cable stayed bridges

Harsha Vardhan
Assistant Professor, Department of Civil Engineering, Brindavan College of Engineering, Bengaluru.
Email: harshavardan305@gmail.com

A C Ravi Patil
Assistant Professor, Department of Civil Engineering R R Institute of Technology, Bengaluru.
Email: ravipatil777@gmail.com

Anushree
Assistant Professor, Department of Civil Engineering Vijaya Vittala Institute of Technology, Bengaluru.
Email: anushree9999@gmail.com

***Abstract*---**The first cable-stayed bridges appeared in Europe in the 1700s. Cable-stayed bridges have been increasingly popular over the past few decades because of its aesthetic appeal, effective use of materials, and availability of innovative building techniques. As a result of the Sutong Bridge's success, numerous other similar bridges have been proposed or are now being built, necessitating further study in this area. In recent years, cable-stayed bridges of very great spans have been completed, and the goal is to expand the span length even further by using girders that are much thinner. As a result, accurate methodologies must be devised that can lead to a full understanding and realistic forecast of the bridge's structural response under diverse load circumstances. Analysis of cable-stayed bridges with a single and two equal side spans has been done in the present testing to know their seismic response. Static and dynamic loads on cable-stayed bridges, as well as the resulting reaction of the bridge as span length and pylon shape change, are the focus of this study. In order to compare static analysis results for different bridge configurations, we compared the mode shapes, time periods and frequencies, and the maximum deck deflection. Axial forces in stay cables and deck deflection have been studied for various bridge configurations under the impact of the seismic reaction spectrum (El Centro).

International Journal of Health Sciences ISSN 2550-6978 E-ISSN 2550-696X © 2022.
Manuscript submitted: 9 May 2022, Manuscript revised: 18 July 2022, Accepted for publication: 27 August 2022

***Keywords*---**Cable stayed Bridge, static, Dynamic, SAP2000, Modeling, Analysis.

Introduction

Cable Stay type bridges have been around a lot longer than a lot of people think and can be traced back more than four centuries. In recent years, starting around the 1970s, cable stay bridges have become increasingly popular, as improvements in materials and technology have resulted in cable stays bridges becoming a fast and economical way to cross medium to long spans (100 to 1000 meters), The cable stay bridge system, which is a unique feature of the new Indian River Inlet Bridge, was a development of the post tension system invented by Mr. Eugene Freyssinet, in France, in the early 1900's. The early designs of modern cable-stayed bridges essentiality consisted of a stiff girder supported by a few cables. The stay forces were rather large and consequently the anchorage design was excessively complex. Static and dynamic analyses are performed on the cable stayed bridge. Static analysis is performed to find the dead load and live load behavior of the structure. The dynamic analysis is to find the dynamic properties of the structure.

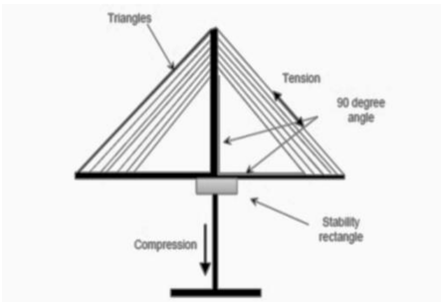

Fig.1. Cable Stayed Bridge

Methodology

The methodology worked out to achieve determined objectives is by following pattern to analyze the cable stayed bridge with reviewing the existing literatures from many researchers. First by selecting a Cable stayed bridge model for the case study and considering the required parameters to analyze the bridge. Later the structure is modeled by using SAP2000 software by adopting different pylon shapes with different span in the bridge, bridge which is subjected to only dead load in modal load combination. The parameters are to studied for different spans of different height of pylon in static analysis and in dynamic analysis dead load, seismic load and moving load in modal load combination.

After modeling is done the analysis is carried out by adopting two methods such as static and dynamic analysis (time history analysis) for bridge considered and a comparative study on the results obtained from the analysis. Later the observation is done for the comparisons and conclusion is stated.

Analytical Program

A. Details of the Bridge

- Bridge Length:
  - i. Type 1 (100m)
  - ii. Type 2 (200m)
  - iii. Type 3 (300m)
  - iv. Type 4 (400m)
- Shape of pylons:
  - i. A-Shape with harp arrangement
  - ii. H-Shape with harp arrangement

- Concrete
  Grade M-45
  Modulus of elasticity for Concrete 33541.02 kN/m2
  Poisson's ratio for Concrete 0.2
  Co-efficient of thermal expansion 1.170* E-05/0C
  Shear modulus 12900392 kN/m2
- Steel
  Grade of Steel 250 N/mm2
  Modulus of elasticity for Steel 1.99*108 kN/m2
  Poisson's ratio for steel 0.3
  Shear modulus 76903069kN/m2
  Link Rigid link
- Cables
  Pre-stressed tendons
  Modulus of elasticity 1.58*108 KN/m2
  Co-efficient of thermal expansion 1.170* E-05/0C
  Shear modulus 60769231kN/m2
  Poisson's ratio 0.3
- Deck
  Concrete box type deck
  Outer width 22m
  Total width 3.2m Flange thickness 1m
  Web thickness 1m

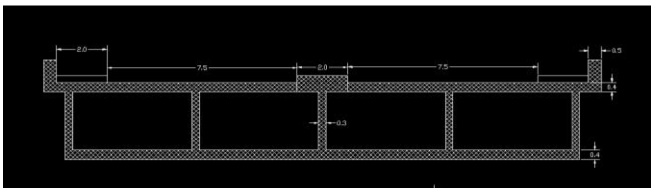

Fig. 2. Deck sectionFrame section properties

I Concrete Beam
Box type

Outer width, T3 : 2.5m
Total depth, T2 3m
Thickness flange, Tf 1m

Thickness web, Tw 1m

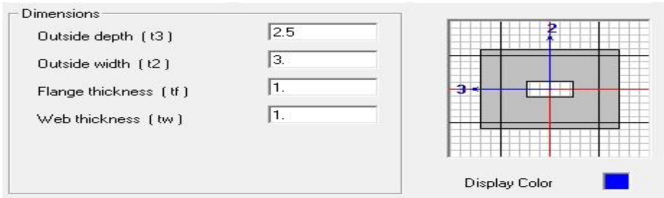

Fig. 3. Dimension selection in SAP2000

II Pylon [It is a non-prismatic section so we have to consider two types of section i.e. top and bottom section details are given below]

Pylon Bottom

- Material : M 45 concrete
- Section : Box/Tube
- Outside depth T_3 : 4m
- Outside widthT_2 : 6m
- Flange thickness T_f : 1.25m
- Web thickness T_w : 2.25m

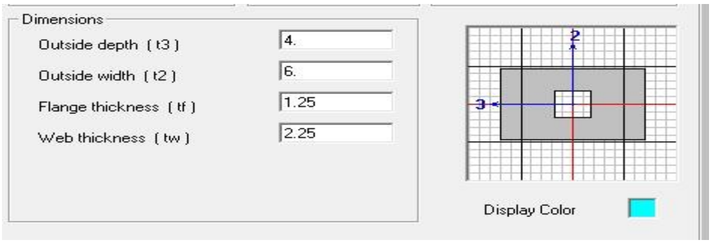

Fig 4 Pylon Bottom Frame Properties

Pylon Top

- Material :M 45 concrete
- Section : Box/Tube
- Outside depth T_3 :3m
- Outside widthT_2 :6 m
- Flange thickness T_f :1 m
- Web thickness T_w :2.25m

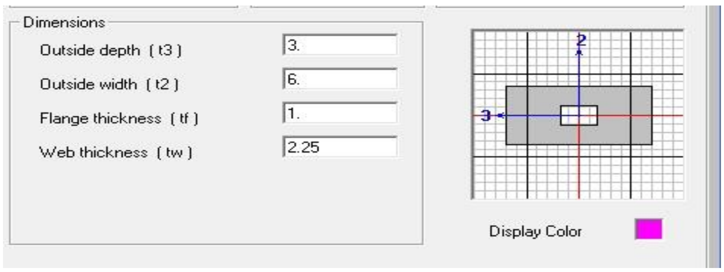

Fig 5 Pylon Top Frame Properties

- Time History Analysis Data:
  Input - ELCENTRO-Earthquake
  Location: "Imperial Valley"

Date: 19th May 1940
Time: 4:39am
Station: "El Centro Array #9"
Direction: Horizontal, 180°
Units of acceleration: g= 9.81 m/s2 (acceleration of gravity)
Number of time instants: 4,000
Sampling time: Δt = 0.01 s (f= 100 Hz)
Time history type – Modal

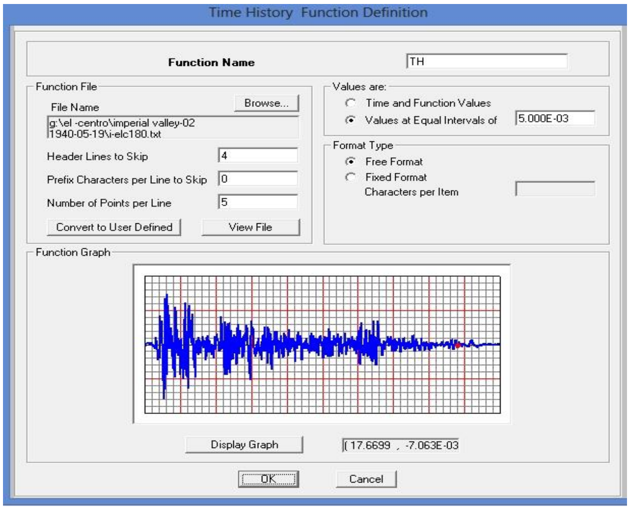

Fig. 4. Time History Function Definition

- Moving Load Analysis:
  Code – IRC -6 Class AA Tracked Vehicle
  Vehicle name-IRC-70R-1
  Vehicle class-IRC-70R
  Over the past three decades, the SAP brand has become synonymous with cutting-edge methodological approaches. An unparalleled analysis engine and design tools for engineers working in the fields of transportation, industrial, public works, sports, and other facilities are at the core of SAP2000's user interface. Like no other programme, SAP2000 optimizes moving load analysis for bridge design. Torque and other reactions can be taken into account by simply shifting the lanes away from the beam centerline. Loads may be applied or restrictions and supports can be assigned with ease using SAP2000, even when they are not parallel to the global axis.

Modeling of Different type of Bridges

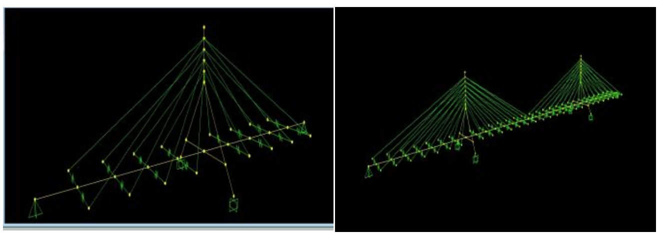

Fig. 5. Models of a type pylon single and doubble

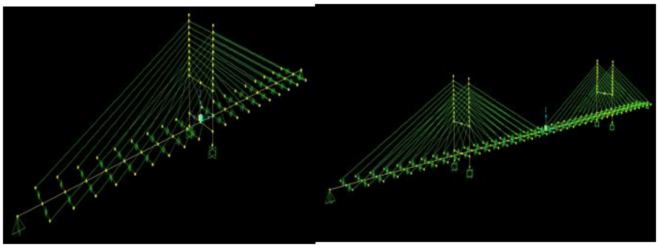

Fig. 6 Model of h type pylon single and doubble

Result and Discussion

The models were analyzed using SAP 2000, the following results like deck box deflection, mode shapes for different time period are extracted and max axial force in the cable stay were obtained and tabulated

Mode Shape A-Type

Table 1 Mode Shape of A –Type

Span in m A type	Mode 1 Time period	Mode 2 Time period	Mode 3 Time period
100	0.31655	0.24469	0.12249
200	0.90555	0.83404	0.83138
300	0.56249	0.44419	0.42758
400	0.77397	0.73804	0.49983

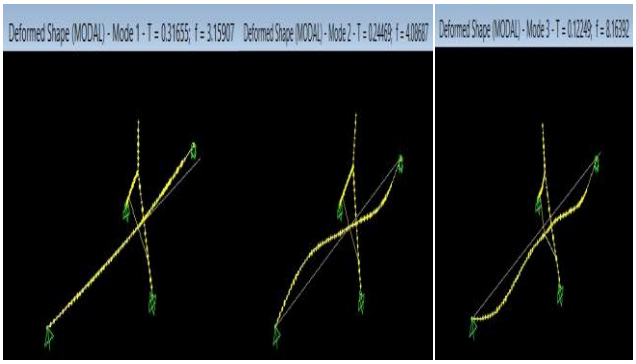

Fig 7 Mode Shape of 100 m Span of A -Type

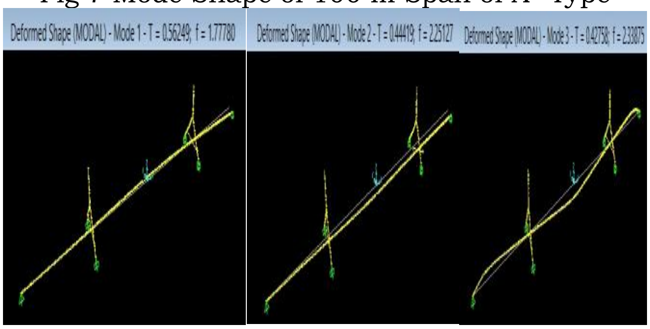

Fig 8 Mode Shape of 300 m Span of A- Type

Mode Shape H Type

Table 2 Mode Shape of H Type

Span in m H type	Mode 1 Time period	Mode 2 Time period	Mode 3 Time period
100	0.29692	0.26474	0.18289
200	0.77390	0.70258	0.65805
300	0.49405	0.46101	0.30147
400	1.05433	0.68673	0.67217

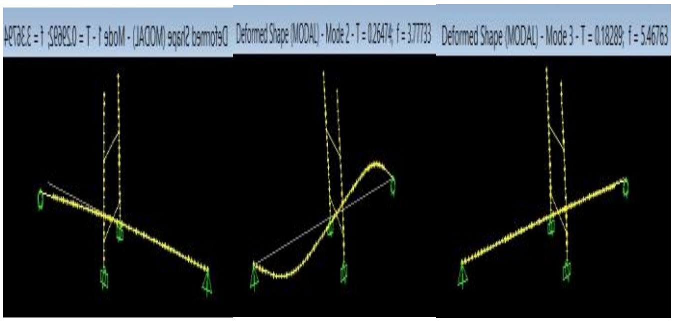

Fig 9 Mode Shape of 100 m Span of H –Type

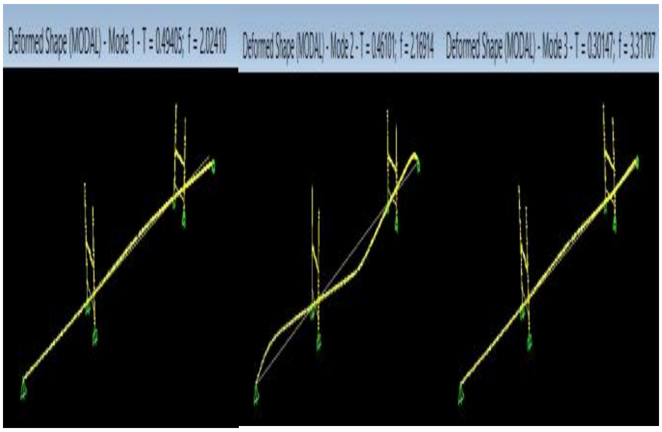

Fig 10 Mode Shape of 300 m Span of H- Type

Bending Moment and Shear Force of A Type

Table 3 Bending Moment of Deck 100 m Span [A-type]

SPAN IN M A	BENDING MOMENT DL+ML IN MM	BENDING MOMENT DL+ML+ ZONE II IN MM	BENDING MOMENT DL+ML+ ZONE III MM	BENDING MOMENT DL+ML+ ZONE IV IN MM	BENDING MOMENT DL+ML+ ZONE V IN MM	BENDING MOMENT DL+ML+TH IN MM
0	0	-7.3E-12	0	0	0	1.14E-10
10	43679.47	40763.28	39013.56	36680.61	33181.18	62383.42
20	22677.04	18162.13	15453.18	11841.24	6423.346	36944.88
30	9226.817	7594.59	6615.254	5309.473	3350.801	16730.25
40	-7809.64	-7431.03	-7203.87	-6900.98	-6446.66	-5274.88
50	15500.41	15556.71	15590.49	15635.52	15703.08	18731.23
60	-21973.5	-21663.6	-21477.6	-21229.6	-20857.7	-15999
70	7450.933	9151.277	10171.48	11531.76	13572.17	12762.94
80	22804	26984.85	29493.35	32838.03	37855.04	36850.71
90	44348.36	46891	48416.58	50450.69	53501.85	66482.9
100	0	0	0	0	0	0

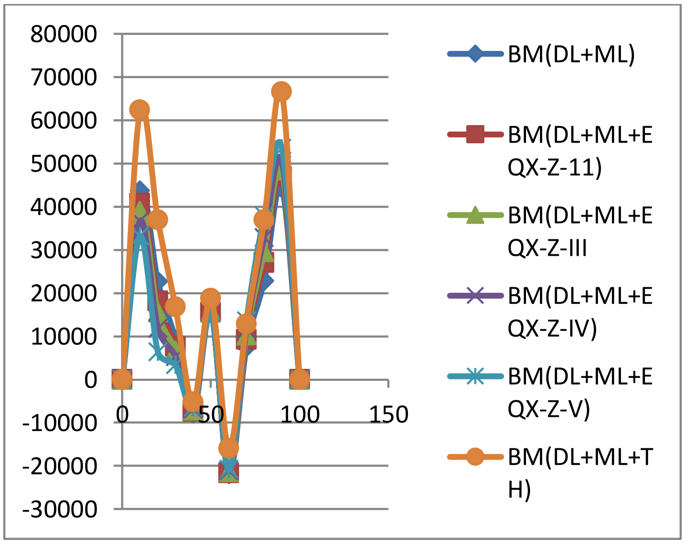

Fig 11 Bending Moment of Deck 100 m Span [A-type]

Table 4 Shear Force of Deck 100 m Span [A-type]

SPAN IN M A	SHEAR FORCE DL+ML IN MM	SHEAR FORCE DL+ML+ ZONE II IN MM	SHEAR FORCE DL+ML+ ZONE III MM	SHEAR FORCE DL+ML+ ZONE IV IN MM	SHEAR FORCE DL+ML+ ZONE V IN MM	SHEAR FORCE DL+ML+TH IN MM
0	-5588.34	-5296.72	-5121.75	-4888.46	-4538.52	-3337.81
10	-312.875	-50.705	106.596	316.332	630.935	750.099
20	5418.87	5554.919	5636.549	5745.389	5908.649	7786.457
30	7482.653	7412.673	7370.685	7314.701	7230.724	10820.58
40	1448.051	1385.345	1347.722	1297.557	1222.311	2419.447
50	203.616	233.963	252.171	276.449	312.865	586.075
60	-7588.59	-7675.12	-7727.03	-7796.26	-7900.09	-4864.31
70	-6308.34	-6352.79	-6379.46	-5415.02	-6468.35	-3787.08
80	-4340.56	-4174.56	-4074.96	-3942.16	-3742.56	-2858.62
90	1680.412	1934.675	2087.233	2290.644	2595.76	3393.866
100	0	0	0	0	0	0

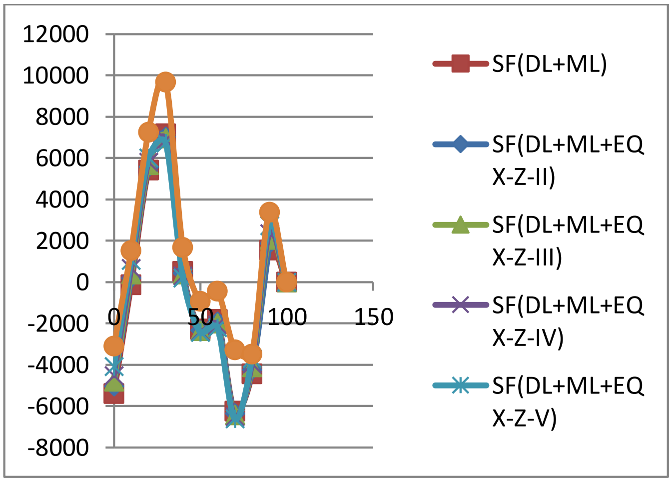

Fig 12 Shear Force of Deck 100 m Span [A-type]

Table 4 Bending Moment of Deck 300 m Span [A-type]

Span in m	BENDING MOMENT DL+ML in MM	BENDING MOMENT DL+ML+ ZONE II in MM	BENDING MOMENT DL+ML+ ZONE III MM	BENDING MOMENT DL+ML+ ZONE IV in MM	BENDING MOMENT DL+ML+ ZONE V in MM	BENDING MOMENT DL+ML+TH in MM
0	-7.3E-12	7.28E-12	-7.3E-12	-2.2E-11	-7.3E-12	-7.3E-12
10	3978.92	1441.98	-80.1846	-2109.74	-5154.07	-5154.07
20	15186.95	12791.56	11354.32	9438.008	6563.538	6563.538
30	16813.58	15615.33	14896.38	13937.78	12499.89	12499.89
40	14152.57	13866.48	13694.83	13465.96	13122.65	13122.65
50	5491.503	5649.765	5744.722	5871.331	6061.246	6061.246
60	-8147.9	-7791.04	-7576.92	-7291.43	-6863.19	-6863.19
70	-14942.7	-14616.9	-14421.4	-14160.7	-13769.7	-13769.7
80	30098.87	30371.35	30534.83	30752.82	31079.79	31079.79
90	-17941.5	-17751.8	-17638	-17486.3	-17258.7	-17258.7
100	-6452.1	-6425.12	-6408.93	-6387.35	-6354.98	-6354.98
110	6183.823	6307.505	6381.714	6480.659	6629.077	6629.077
120	13765.4	14260.35	14557.32	14953.27	15547.21	15547.21
130	17495.82	18553.18	19187.6	20033.49	21302.32	21302.32
140	22954.7	24513.45	25448.71	26695.71	28566.22	28566.22
150	30586.64	31517.88	32076.63	32821.62	33939.11	33939.11
160	39734.18	39052.68	38643.79	38098.59	37280.8	37280.8
170	35040.06	32745.72	31369.11	29533.63	26780.41	26780.41
180	29533.25	27315.3	25984.54	24210.18	21548.65	21548.65
190	20861.76	19657.42	18934.82	17971.34	16526.13	16526.13
200	15879.62	15569.82	15383.95	15136.11	14764.36	14764.36
210	16530.43	16561.85	16580.69	16605.83	16643.52	16643.52
220	-13955	-13494.2	-13217.7	-12849	-12296	-12296
230	-23116.9	-22756.8	-22540.7	-22252.6	-21820.4	-21820.4
240	27597.55	27693.15	27750.51	27826.99	27941.71	27941.71
250	-15049.7	-15243.7	-15360.1	-15515.3	-15748.1	-15748.1
260	-5144.17	-5448.5	-5631.09	-5874.56	-6239.75	-6239.75
270	6596.35	6558.745	6536.183	6506.099	6460.974	6460.974
280	13089.74	13667.74	14014.54	14476.94	15170.54	15170.54
290	15082.31	16649.15	17589.25	18842.72	20722.92	20722.92
300	0	0	0	0	0	0

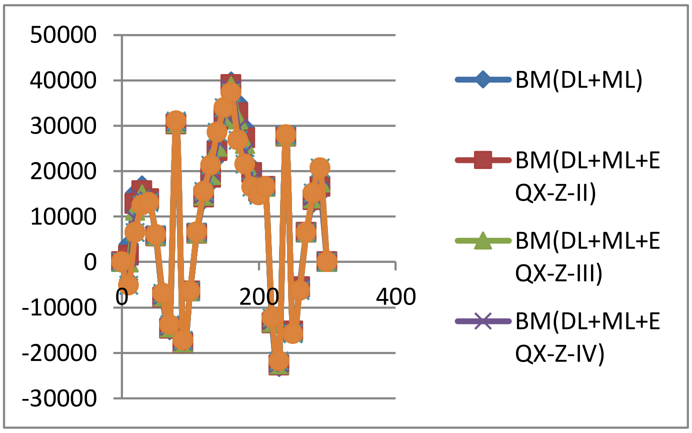

Fig 13 Bending Moment of Deck 300 m Span [A-type]

Table 5 Shear Force of Deck 300 m Span [A-type]

Span in m	SHEAR FORCE DL+ML in MM	SHEAR FORCE DL+ML+ ZONE II in MM	SHEAR FORCE DL+ML+ ZONE III MM	SHEAR FORCE DL+ML+ ZONE IV in MM	SHEAR FORCE DL+ML+ ZONE V in MM	SHEAR FORCE DL+ML+TH in MM
0	511.341	1018.696	1323.109	1728.993	2337.818	2337.818
10	2871.264	3341.232	3623.213	3999.188	4563.15	4563.15
20	1847.743	1820.84	1804.698	1783.175	1750.891	1750.891
30	2548.824	2431.917	2361.774	2268.249	2127.961	2127.961
40	3104.532	3010.1	2953.44	2877.895	2764.576	2764.576
50	4020.905	3965.498	3932.255	3887.93	3821.442	3821.442
60	4515.629	4483.743	4464.611	4439.101	4400.837	4400.837
70	-1219.72	-1219.85	-1219.93	-1220.03	-1220.19	-1220.19
80	2361.646	2367.252	2370.616	2375.101	2381.828	2381.828
90	-3277.17	-3273.28	-3270.95	-3267.83	-3263.16	-3263.16
100	-3176.95	-3208.5	-3227.43	-3252.67	-3290.53	-3290.53
110	-2309.37	-2380.03	-2422.42	-2478.94	-2563.73	-2563.73
120	-1684.02	-1782.59	-1841.73	-1920.59	-2038.87	-2038.87
130	-1499.97	-1615.04	-1684.08	-1776.14	-1914.22	-1914.22
140	-1562.75	-1591.44	-1608.66	-1631.62	-1666.06	-1666.06
150	-2378.12	-2055.58	-1862.05	-1604.01	-1216.95	-1216.95
160	436.664	759.212	952.74	1210.778	1597.834	1597.834
170	2975.276	3280.495	3463.626	3707.801	4074.064	4074.064
180	3598.436	3509.671	3456.411	3385.398	3278.879	3278.879
190	3775.418	3614.544	3518.02	3389.321	3196.273	3196.273
200	3543.422	3409.086	3328.484	3221.015	3059.812	3059.812
210	3213.245	3137.159	3091.507	3030.639	2939.335	2939.335
220	6343.223	6284.201	6248.787	6201.569	6130.742	6130.742
230	-1284.3	-1278.95	-1275.75	-1271.47	-1265.05	-1265.05
240	1841.244	1865.018	1879.283	1898.303	1926.832	1926.832
250	-2947.51	-2961.05	-2969.17	-2980	-2996.25	-2996.25
260	-2819.88	-2886.08	-2925.8	-2978.77	-3058.22	-3058.22
270	-1795.08	-1912.14	-1982.37	-2076.02	-2216.49	-2216.49
280	-1012.06	-1173.85	-1270.92	-1400.34	-1594.48	-1594.48
290	-317.141	-509.686	-625.213	-779.249	-1010.3	-1010.3
300	0	0	0	0	0	0

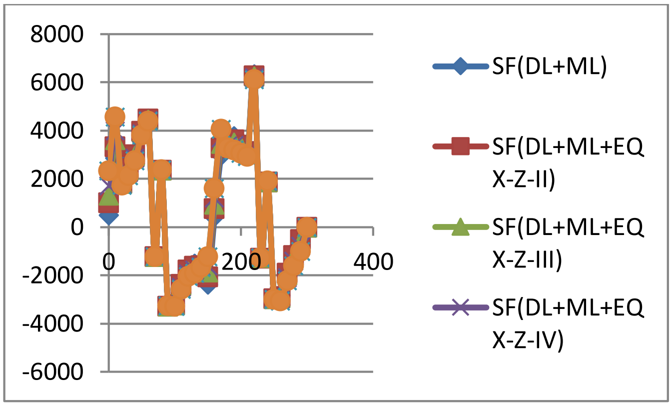

Fig 14 Shear Force of Deck 300 m Span [A-type]

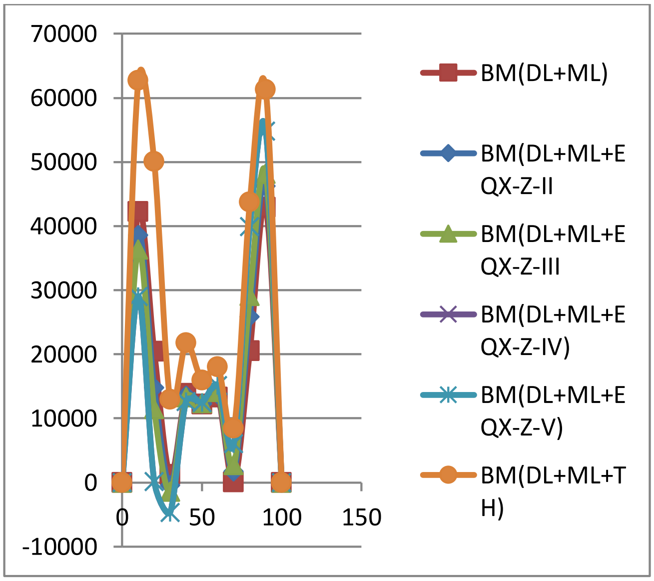

Fig 15 Bending Moment of Deck 100 m Span [H-type]

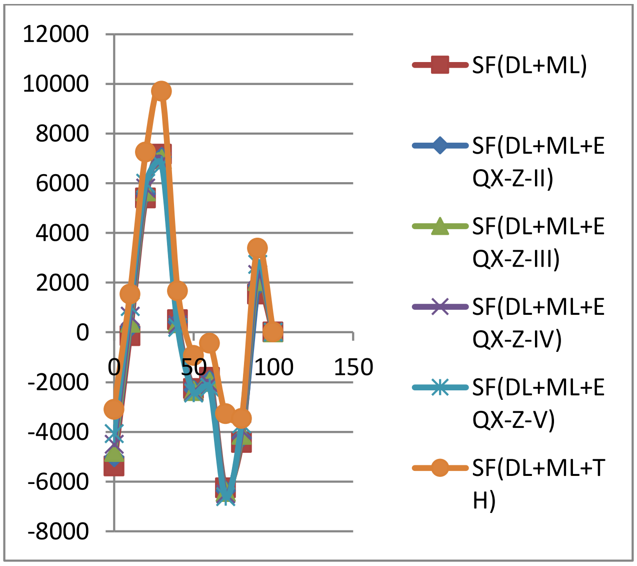

Fig 16 Shear Force of Deck 100 m Span [H-type]

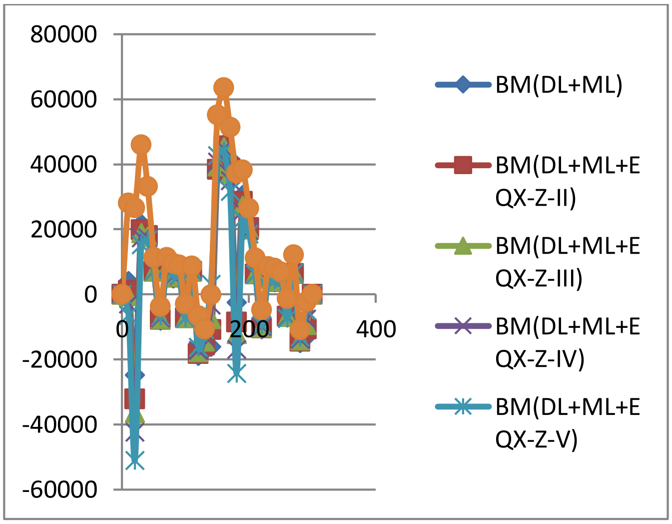

Fig 17 Bending Moment of Deck 300 m Span [H-type]

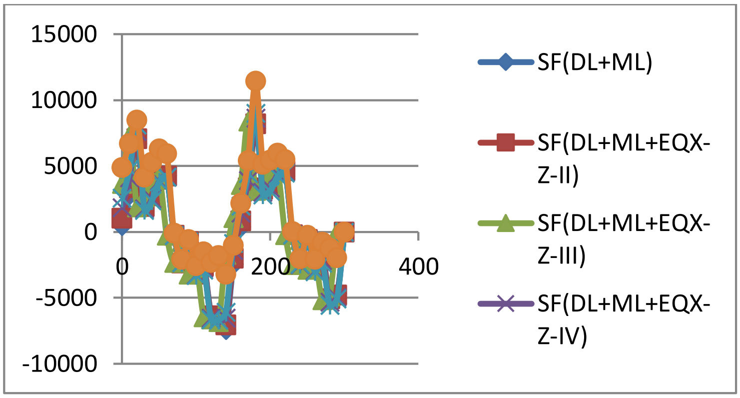

Fig 18 Shear Force of Deck 300 m Span [H-type]

Deck Deflection for A Type

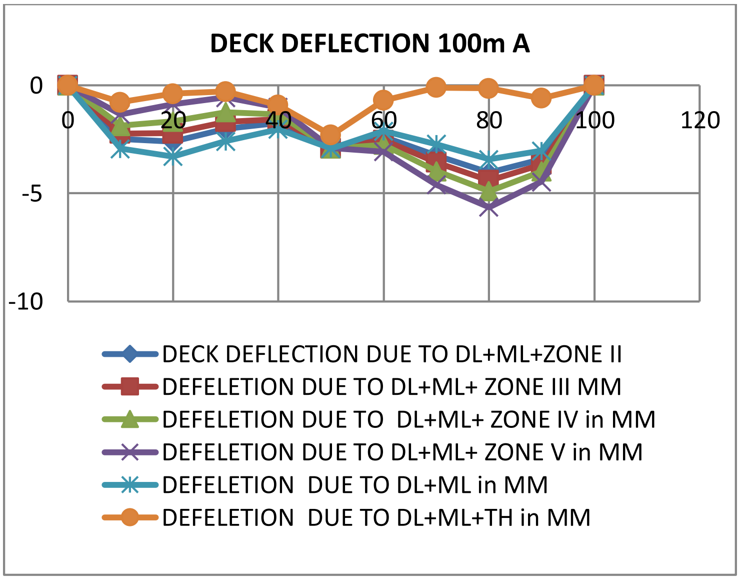

Fig 19 Graph 1 Deck Deflection 100m Span [A type]

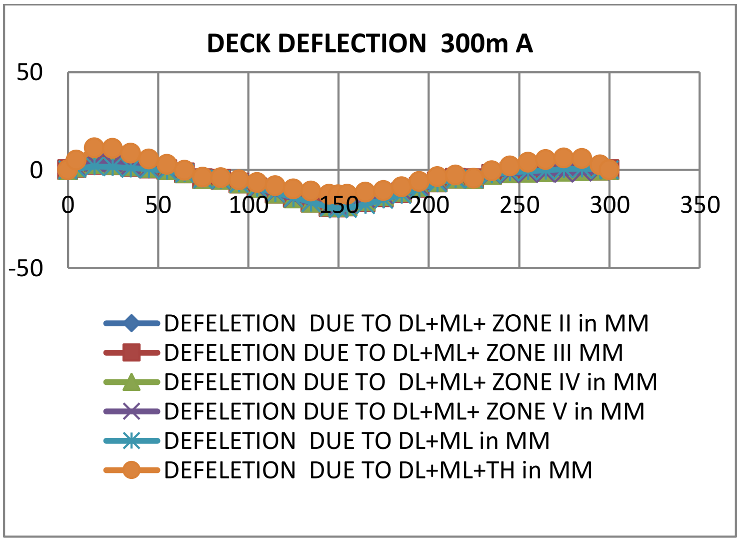

Fig 20 Graph 2 Deck Deflection 300m Span [A type]

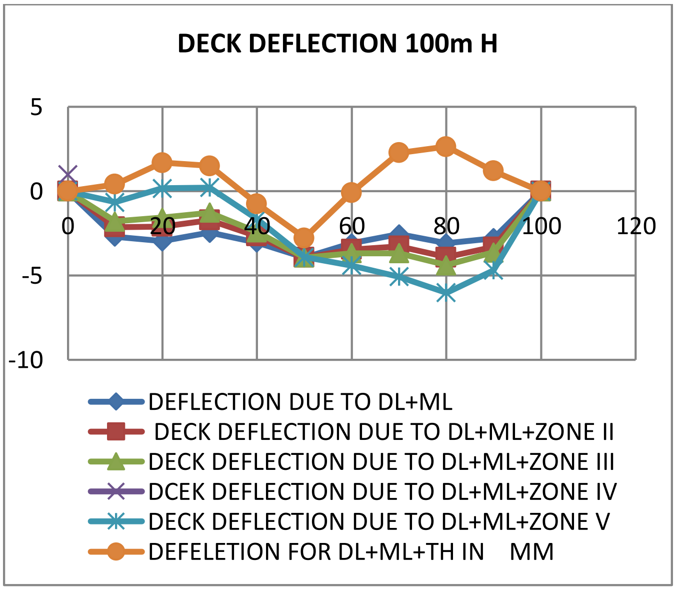

Fig 21 Graph 3 Deck Deflection 100m Span (H type)

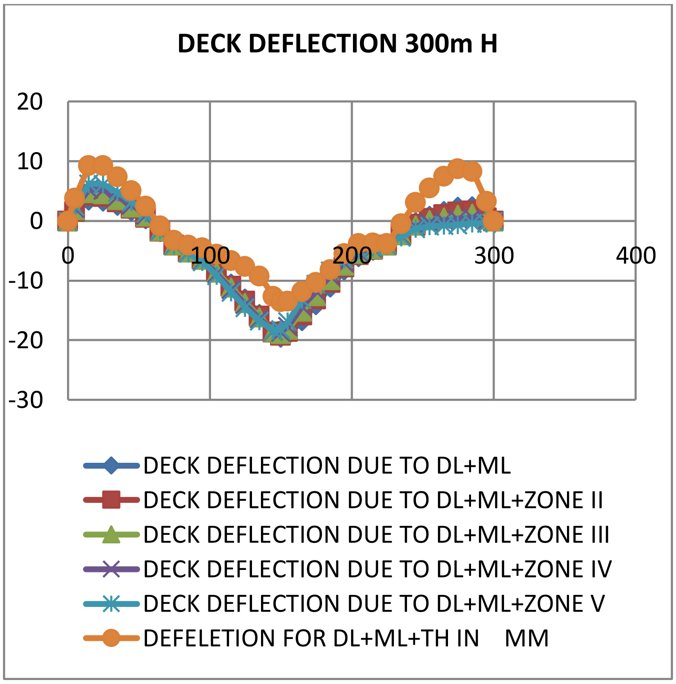

Fig 22 Graph 7 Deck Deflection 300m Span (H type)

Deck Deflection of and H type for 100,200,300m &400m Spans

Single pylon of A type used form deck deflection goes on decreases as the lateral load included in the load combination In case of 200m cable stayed bridge deflection goes on increases as the lateral force included but since span is increasing the deflection is also increasing Double pylon of A type used form deck deflection goes on increases as the lateral load included in the load combination In case of 400m cable stayed bridge deflection goes on increases as the lateral force included but since span is increasing the deflection is also increasing

Cable Axial Force

TYPE OF MODEL	LOAD CASE	MAX TENDON AXIAL FORCE IN KN
A-TYPE 100M SPAN	DEAD	6906.342
Single pylon	DL+ML	7651.99
	DL+ML+EQX_Z_II	7616.071
	DL+ML+EQX_Z_III	7667.371
	DL+ML+EQX_Z_IV	7735.771
	DL+ML+EQX_Z_V	7838.371
	DL+ML+TH	9873.679
A-TYPE 200M SPAN	DEAD	11651.037
Single pylon	DL+ML	12742.661
	DL+ML+EQX_Z_II	12869.205
	DL+ML+EQX_Z_III	12945.132
	DL+ML+EQX_Z_IV	13046.367
	DL+ML+EQX_Z_V	13198.22
	DL+ML+TH	12743.452
A-TYPE 300M SPAN	DEAD	8252.72
Double pylon	DL+ML	9438.137
	DL+ML+EQX_Z_II	9998.06
	DL+ML+EQX_Z_III	10438.576
	DL+ML+EQX_Z_IV	11025.931
	DL+ML+EQX_Z_V	11906.963
	DL+ML+TH	16943.409
A-TYPE 400M SPAN	DEAD	12464.909
Double pylon	DL+ML	14328.464
	DL+ML+EQX_Z_II	15252.329
	DL+ML+EQX_Z_III	15806.648
	DL+ML+EQX_Z_IV	16545.74
	DL+ML+EQX_Z_V	16545.74
	DL+ML+TH	15235.643

Cable Axial Force

Max Cable Axial Force100 and 200m Span of A and H Type

The table 5.11 shows the maximum value of cable axial force value of different span cable stay bridge for different span i.e. 100,200,300,400m with different, pylon shape A and H type with different load case, the maximum axial force goes on increases with, Dead Load, DL+ML,DL+ML+EQX-ZII,DL+ML+EQX-ZIII,DL+ML+EQX-ZIV,DL+ML+EQX-ZV& Time History, & as the span increases the axial force in cable also goes on increasing and for single pylon100m span the combination of DL+ML+EQ-ZV [7838.371KN] gives the maximum axial force in static analysis and combination DL+ML+TH [9873.679]load case gives maximum axial force in dynamic analysis. The effect of span can be treated as the slenderness effect, in case of single pylon of Shape. The maximum value of axial force is observed in load combination, dynamic analysis i.e. DL+ML+TH, compare to static case, i.e. DL+ML+EQX-ZV and in 200m span of A shape It has been observed that higher slenderness the axial force is maximum in static load case [13198.22 KN] compare to dynamic load case [12743.452 KN] in this stage we need to consider the slenderness. The above graph shows the variation.

Max Cable Axial Force300 and 400m Span of A and H Type

The table 5.11 shows the maximum value of cable axial force value of different span cable stay bridge for different span i.e. 100,200,300,400m with different, pylon shape A and H type with different load case, the maximum axial force goes on increases with, Dead Load, DL+ML, DL+ML+EQX-ZII,DL+ML+EQX-ZIII,DL+ML+EQX-ZIV,DL+ML+EQX-ZV & Time History, & as the span increases the axial force in cable also goes on increasing and for Double pylon300m span the combination of DL+ML+EQ-ZV [11906.963KN] gives the maximum axial force in static analysis and combination DL+ML+TH [16943.409KN] load case gives maximum axial force in dynamic analysis. The effect of span can be treated as the slenderness effect, in case of single pylon of A shape. The maximum value of axial force is observed in load combination, dynamic analysis i.e. DL+ML+TH, compare to static case, i.e. DL+ML+EQX-ZV and in 400m span of A shape It has been observed that higher slenderness the axial force is maximum in static load case[16545.74 KN] compare to dynamic load case [15235.643KN] in this stage we need to consider the slenderness .The above graph shows the variation.

Conclusions

Simple method of modeling of cable styed bridge with different pylon has been carried and by carrying seismic and moving load analysis has been done..

Dynamic Analysis:

[1] The dynamic analysis results shows that for the cable stayed bridge with H type pattern pylon will have lesser value of fundamental time period compare to A type and this shape is economical in design.
[2] Even the slenderness effects play an important role in dynamic analysis i.e. for span/pylon height the Ratio is higher means the fundamental model time period will be usually higher value.
[3] In case of H shape pylon Cable stayed bridge of higher slenderness ratio the modal time period value will be usually less.

Deck Deflection:

[4] As lateral load effect increases the deflection goes on Decreases
[5] Dynamic analysis such as time history gives the worst effect of lateral load in case of deck deflection.
[6] H-shape pylon is effective to control the deck deflection compare to A shape pylon.

Axial Force in Cable:

[7] In case of double pylon of less slenderness ratio the axial force will be maximum in time history analysis.
[8] H-shape pylon will experience lesser axial force in cable stay compare to A shape pylon cable stayed bridge.
[9] In case of single pylon of higher slenderness ratio the axial force will be maximum in time history analysis or in worst combination.

References

1. The thesis by Olfat Sarhang Zadeh, Comparison Between Three Types of Cable-Stayed Bridges Using Structural Optimization. London, Ontario, Canada4 October, 2012
2. H. Saidi , M. Al-Rawi , A.F. Ali and A. Adda
   “Response Characteristic of Cable Stayed Bridges under Static Loading and Due to the Earthquakes in Longitudinal Direction” 2014
3. Moeen Sakran and D. S. Prakash Rao, “cable stayed bridges for elegance and economy” The University of the West Indies, Trinidad and Tobago-2010.
4. Chun-Ho H, Yang-Cheng W., “Three –Dimensional Modeling of A Cable Stayed Bridge for Dynamic Analysis “Dept. of Civil Engineering, Chinese Military Academy, Feng-Shan 83005, Taiwan, China.
5. Atul K. Desai,” Seismic Time History Analysis for Cable-Stayed Bridge Considering Different Geometrical Configuration For Near Field Earthquakes” World Academy of Science, Engineering and Technology 79, 2013.
6. IRC-6-2000 standard specifications and code of practice for road bridges, section II, loads and stresses, Fourth Revision
7. IS 1983(part-I):2000, Criteria for earthquake resistant design of structures