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Parametric Study of Cable Stayed Bridge with Different Cable Configurations Subjected to Lateral Load

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Abstract - *Cable stayed bridges are becoming more popular all around the world due to its flexibility, aesthetic appearance, efficient utilization of material and relatively low construction costs. Cable stayed bridges consist of one or more pylons with cables supporting the deck. Due to its flexible nature, cable stayed bridges are very sensitive to lateral loads. Also it has been observed that changing the cable configuration can cause change in force acting on bridge components, resulting change in their dimensions and finally cause the overall construction costs. In the present study, an attempt has been made to analyze the seismic response of cable stayed bridges. Three cable configurations fan, semi-fan, and harp have been considered with H-shape pylon. Effect of seismic action has been studied with varying span length of 700m, 850m, 1000m using MIDAS civil software. Non-linear time history analysis has been performed considering time history El-centro 1940 earthquake and cable forces, bending moment, axial force, torsion in pylon and deck has been computed. Finally, comparison is carried out considering different parameters to provide the best suitable cable configuration.*

***Key Words*: Cable stayed bridge, Cable configuration, fan, semi-fan, harp, non-linear time history analysis, Midas civil**

1. INTRODUCTION

The basic concept is the utilization of high strength cables to provide intermediate supports for the girder so that it may span a much longer distance. The cable-stays are directly connected to the bridge deck resulting in much stiffer structure. A large number of closely spaced cable stays support the bridge deck through its length thus reducing the required bending stiffness of the longitudinal to the minimum and thus allowing easy construction of longer spans. The structural system is a triangulated force system in which cables are in tension while there is compression in pylons and deck. The secondary effects like bending, shear, deformation of structure plays pivotal role in stress determination of members and change the stresses considerably.

However, Cable-stayed bridges can also be economically designed for medium and short spans by allotting appropriate stiffness to the cables, tower(s) and girder. Cable stayed bridges have therefore also been used for short span pedestrian bridges and aqueducts because of their pleasing form and are very quick to construct. There is still place for innovation in Cable-stayed bridge techniques, and the increase in their span length occurring during this last decade of the 21st century is remarkable. The Cable stayed bridge seems to be a developing bridge type of this era. Earlier, Designs of cable stayed bridges essentially consisted of a stiff girder support by a few cable. The stay forces were rather and consequently the anchorage design was exclusively complex. Further development indicated that these problems could be eliminated by increasing the number of stays.

The main objectives of the research are

1. To analyze the cable stayed bridge with different cable configurations considering varying span lengths like 700m, 850m and 1000m under seismic action.
2. Provide best suitable option for particular span length keeping bending moment of deck and pylon, axial forces in deck and pylon, torsional moment in deck and pylon and cable forces.

2. MODELING IN SOFTWARE

The following was applied to reach above objectives:

Table -1: Material properties of bridge components

Components	Modulus of elasticity (kN/m^2)	Poison's ratio	Weight density (kN/m^3)
Deck	3.6×10^7	0.2	25
Pylon	2×10^8	0.3	78.5
Cable	1.9×10^8	0.3	78.5

Table -2: Sectional properties of bridge components

Components	Area(m^2)	Ixx(m^4)	Iyy(m^4)	Izz(m^4)
Deck	15.18	67.23	22.76	462.76
Pylon	0.46	0.43	0.29	0.29
Cable	0.02	3.2×10^{-5}	3.2×10^{-5}	3.2×10^{-5}

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Design criteria as per guidelines:

Design criteria 1 : Back span to main span ratio

The ratio between back span to main span should be less than 0.5. Optimum ratio can be considered as 0.4-0.45.

Design criteria 2 : Cable spacing

It has been observed that For deck having depth upto 4m spacing of cable should not be more than 18-30m.

Design criteria 3 : Pylon Height

The height of pylon will determine the overall stiffness of the structure. The optimum ratio of pylon height above the deck to main span is between 0.2 and 0.25.

Table -3: Other details of bridge components

Total span	Side span	Main span	Pylon height
700m	170m	360m	80m
850m	200m	450m	100m
1000m	240m	520m	120m

Table -4: Model details of members

Components	Model as	Material
Deck	Beam Element	Concrete
Pylon	Beam element	Steel
Cable	Truss element	Steel

2.1 Support condition:

Pylon is kept fixed at the bottom. The deck has a roller support at the pylon. The right abutment support is a hinge one while the left support is a roller support.

H shape pylon is used so that all three kind of cable layout can be analyzed. Cable spacing is kept same for all the models which is 15m.

3. EARTHQUAKE LOADING

For non linear time history analysis, El centro 1940 earthquake is taken for study. Details of earthquake and graph are shown

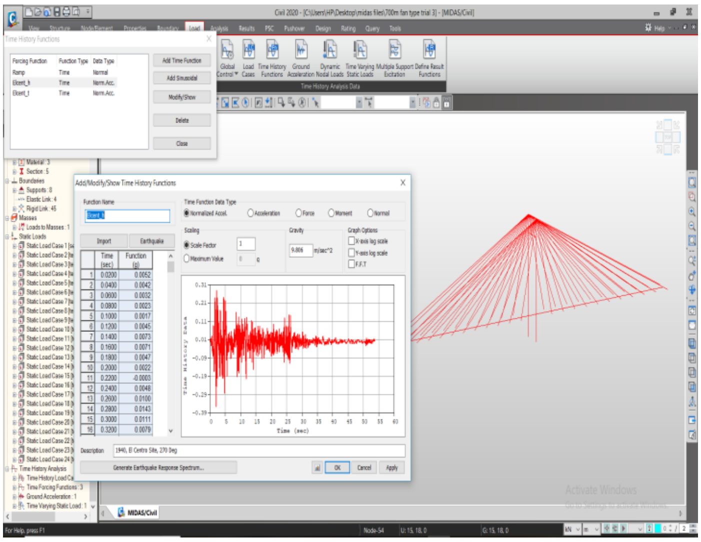

Fig -1: El-Centro earthquake details in MIDAS

Location: Southern California
Year: 18th may,1940
Magnitude: 6.7 (on richter scale)
Duration: 31.1 sec
Excitation type: Medium
Number of steps: 2674
Step size: 0.02
Time History type: Modal
Occurrence of Maximum acceleration: 11.472 sec

4. ANALYSIS AND RESULTS

Results of non linear time history analysis of all three cable configurations are shown below.

Table -5: Results of 700m El centro Earthquake

Parameters	Fan	Semi Fan	Harp
BM at Deck(kNm)	198852	186643	201365
BM at Pylon(kNm)	32228	10727	45236
Axial force at deck(kN)	123469	133498	148635
Axial force at pylon(kN)	122001	119606	120053
Torsional moment at deck(kNm)	24969	26820	35280
Torsional moment at pylon(kNm)	889	947	1205
Cable forces(kN)	12664	15293	32658

Table -6: Results of 850m El centro Earthquake

Parameters	Fan	Semi Fan	Harp
BM at Deck(kNm)	229460	198263	208657
BM at Pylon(kNm)	31190	11894	45963
Axial force at deck(kN)	172295	160332	186325
Axial force at pylon(kN)	156784	206321	213564
Torsional moment at deck(kNm)	22643	24811	26337
Torsional moment at pylon(kNm)	711	857	1023
Cable forces(kN)	18111	21469	36325

Table -7: Results of 1000m El centro Earthquake

Parameters	Fan	Semi Fan	Harp
BM at Deck(kNm)	241683	215093	263571
BM at Pylon(kNm)	34359	16776	38962
Axial force at deck(kN)	184459	205413	211639
Axial force at pylon(kN)	182131	182716	189634
Torsional moment at deck(kNm)	18967	19978	23546
Torsional moment at pylon(kNm)	480	700	911
Cable forces(kN)	16238	16963	38210

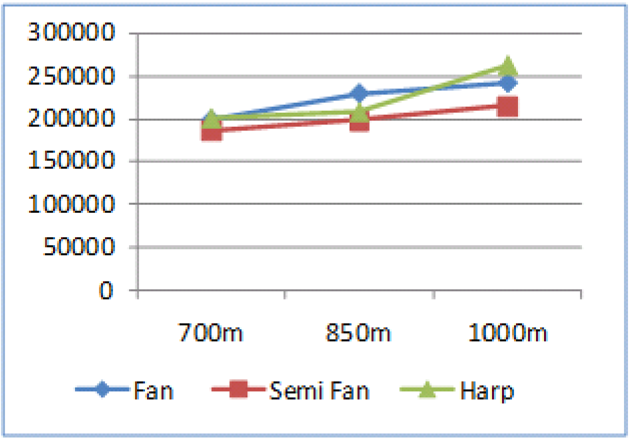

Chart-1: Bending Moment at Deck(kNm)

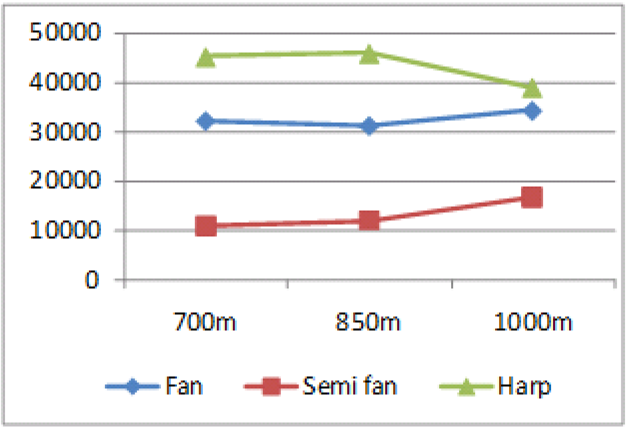

Chart-2: Bending Moment at Pylon(kNm)

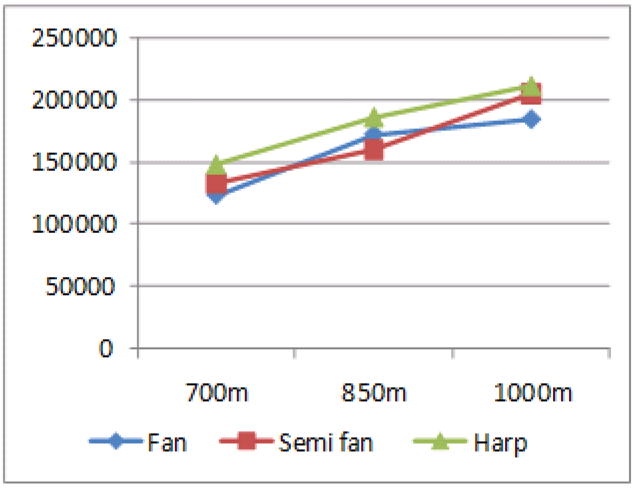

Chart-3: Axial Force at Deck (kN)

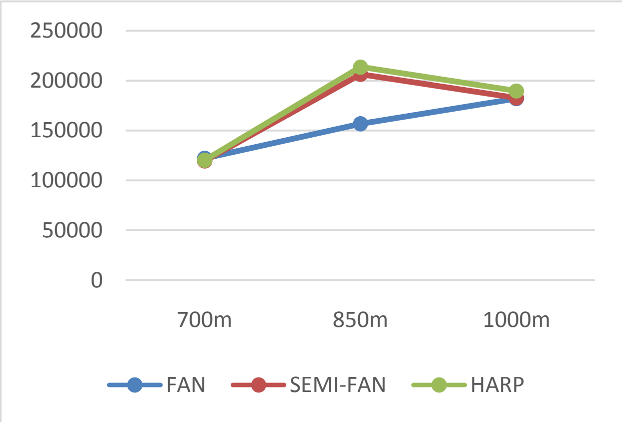

Chart-4: Axial force at Pylon (kNm)

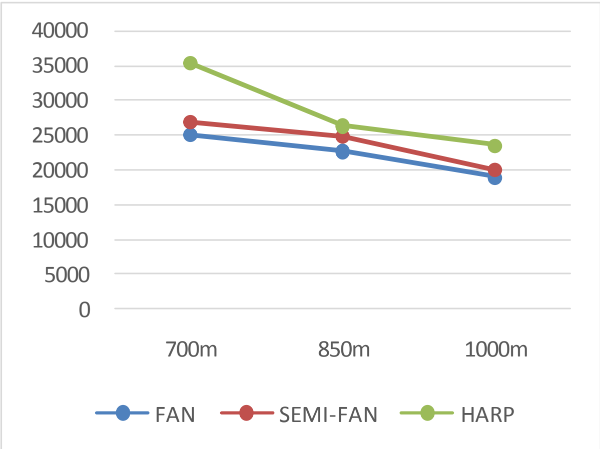

Chart-5: Torsional moment at deck (kNm)

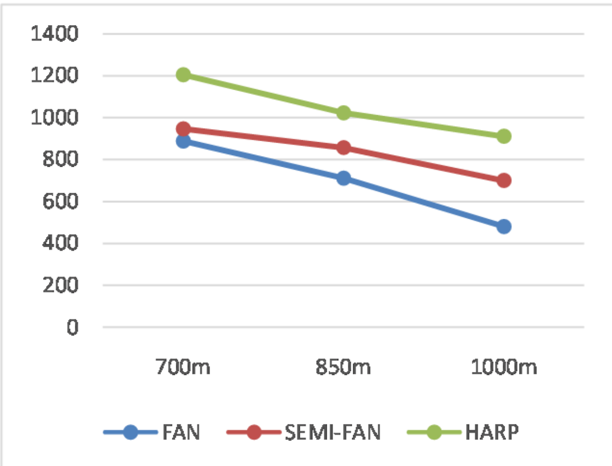

Chart-6: Torsional Moment at Pylon (kNm)

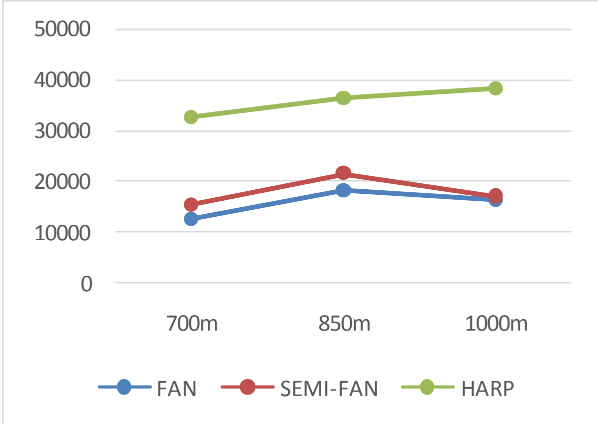

Chart-7: Cableforces (kN)

5. CONCLUSION

Girder forces:

1). From the non linear time history analysis, it can be seen that ***semi fan*** type of cable layout gave lesser value of **bending moment in deck** compare to other cable layout for all the considered span length. Semi fan type cable system gave **7.31%, 13.6% and 18.4%** less value than that of harp type cable system for 700m,850m and 1000m span respectively.

2). The axial force was found minimum in the case of ***fan type*** cable layout in 700m and 1000m span length where semi fan gave minimum result in case of 850m span. while it was maximum for harp type. Fan type cable system gave **7.51% and 10.20%** less value compare to semi fan, For 700m and 1000m respectively.

3). Semi fan cable arrangement gave intermediate value for torsional moment in deck, in all three span while ***fan cable arrangement*** gave minimum value and maximum value observed when harp system is used.

Pylon forces:

1). The pylon moment in the transverse direction of the bridge was found minimum for ***semi fan type*** cable layout and it was very low compared to other layouts. Semi fan gave **76.28%, 74.12% and 56.94%** less value compare to harp system.

2). Axial force in pylon is found out to be minimum for ***semi fan*** also very close results came for fan and harp type, in 700m and 850m span. And it is nearly same for fan type and semi fan type cable system, when 1000m span is considered.

3). ***Fan type*** cable arrangement gives better results in torsional moment in pylon, and it is **26.22%, 40.89% and 47.31%** less than harp type cable arrangement for 700m, 850m and 1000m respectively. Semi fan gave intermediate results.

Cable forces:

1). Cable forces were found maximum for harp type. Gave **53.17%,42.35% and 55.6**% more than semi fan type cable system

Finally, it has been observed that Semi fan cable layout gives better result in case of Bending moment in deck, Bending moment in pylon and axial force in pylon for all three considered spans. As far as axial force in girder and torsional moments are concern, fan type cable arrangement is suitable. So, by analysis it is concluded that fan or semi fan type cable layout is preferred over harp cable layout in long span cable stayed bridges.

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