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Comparative Study on the Effect of Structural Configuration on Seismic Analysis of Cable Stayed Bridge Using SAP 2000

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Abstract— The subject of seismic response of cable stayed bridges has received increasing attention in recent years as these types of bridges are widely designed for large crossing projects. This paper provides a comparative study on the effects of structural configuration (i.e., shape of pylon and cable arrangement) on seismic analysis of cable stayed bridges. The modeling of bridge is prepared on SAP 2000 software and was analyzed as FEM model using non-linear time history analysis. The parameters considered in the study are Base shear, Mid-Span displacement and Tower Head displacement. The study revealed that the fan type cable arrangement and H-shape pylon is found to be effective in earthquake prone areas.

Keywords— Base shear, Cable stayed bridge, Mid-span displacement, Pylon, SAP 2000, Time History Analysis, Tower head displacement.

INTRODUCTION

The cable-stayed bridge finds wide application in engineering for its convenience in construction and economy factor [5]. Many cable stayed bridges have been successfully built around over the world in only last two decades of the 20th century. Due to their highly appreciable appearance & significantly utilized structural materials, cable stayed bridges have been taken as one of the most popular type of bridges in last decades. With increasing span length, the modern cable stayed bridges are more acceptable & flexible strong enough to the effect wind as compare to ever. A typical cable stayed bridge consists of deck with one or two pylons erected above the piers in the middle of the span. The cables are attached diagonally to the girder to provide additional supports [3].

In recent years, several cable-stayed bridges have been constructed with different shapes of pylons such as single pylon, double pylon, H-shaped, A-shaped, Diamond shaped, Inverted Y-shaped etc. which results in a great demand to evaluate the effects of different shapes of pylon on cable stayed bridges under the seismic effect. Therefore, there is a need to study the behavior of the bridge system having conventional pylons under seismic loading. For study of such phenomenon computational analysis of bridges using finite element programs.

The purpose of the pylons is to support the cable system and transfer forces to the foundations. They are loaded with high compressions and bending moments that depend on the stay cable layout and the deck-pylon support conditions. Pylons can be made of steel or concrete, being the latter generally more economic considering similar stiffness conditions. Thus, the dynamic response of the pylons will be conditioned by several aspects, and in addition to the previous idea, the geometric shape of the pylons, which depends on the applied loads, cable-stay system and aesthetic conditions, is a very important aspect [3].

The dynamic effects under the effect of seismic loading were studied by the software SAP 2000. SAP 2000 is finite element based program and is recognized by international community for the research purpose.

ANALYTICAL INVESTIGATION

SAP2000 is a stand-alone finite-element-based structural program for the analysis and design of civil structures. It offers an intuitive, yet powerful user interface with many tools to aid in the quick and accurate construction of models, along with the sophisticated analytical techniques needed to do the most complex projects.

A. Material properties

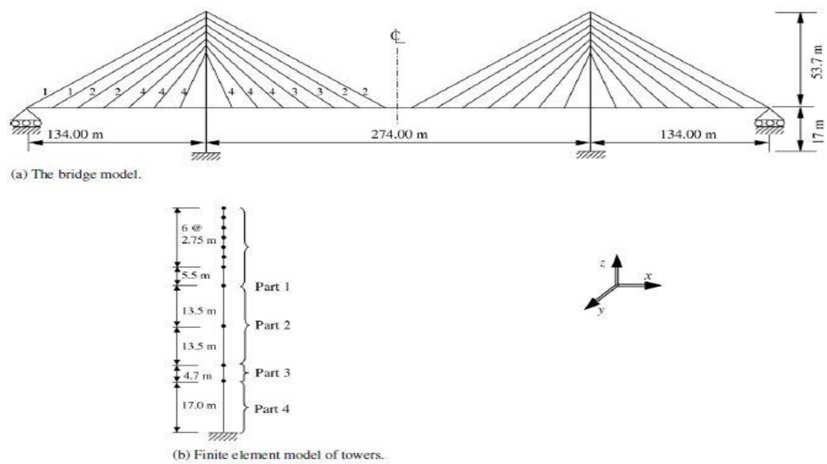


Fig.1. Details of materials used in bridge [1]

Table 1

Properties of the deck and towers of cable stayed bridge [1]

Part of the structure	Cross-sectional area(m^2)	Moment of inertia about z-z axis(m^4)	Moment of inertia about y-y axis(m^4)	Moment of inertia about x-x axis(m^4)	Young's modulus(MPa)	Mass density (kg/m^3)
Deck	0.827	0.341	19.760	0.027	205000	7850
Tower part 1	14.120	28.050	531.670	15.390	30787	2400
Tower part 2	14.120	28.050	670.970	15.390	30787	2400
Tower part 3	17.450	30.620	1239.400	19.760	30787	2400
Tower part 4	35.390	32.750	1422.420	27.640	30787	2400

Table 2

Properties for the stay cables of the cable stayed bridge [1]

Cable no.	Cross-sectional area(m^2)	Young's modulus(MPa)	Cable weight (N/m)
1	0.0180	205000	1765.80
2	0.0135	205000	1324.35
3	0.0107	205000	1049.67
4	0.0070	205000	686.70

B. Loads

The seismic response of the cable-stayed bridge is investigated under four different real earthquake ground motions, namely (i) Imperial Valley, 1940, (ii) Kobe, 1995, (iii) Loma Prieta, 1989, and (iv) Northridge, 1994 earthquakes. The first one has been used widely by researchers in the past, and the last three represent strong earthquake motion records. Although in the present study the four seismic acceleration records have been taken from the database, in professional applications, deeper attention should be devoted to the sample (and its size) of the excitation time histories. The peak ground accelerations (PGAs) of selected earthquake ground motions are shown in Table 3.

Table 3

Earthquake	Recording station	Applied direction of bridge		
		Longitudinal PGA (g)	Transverse PGA (g)	Vertical PGA (g)
Imperial Valley,1940	El Centro	0.060	0.060	0.040
Kobe,1995	Nishi-Akashi	2.220	1.530	1.600
Loma Prieta,1989	Los Gatos - Lexington Dam	1.220	1.100	0.460
Northridge,1994	Sylmar Converter Station	1.800	1.720	2.430

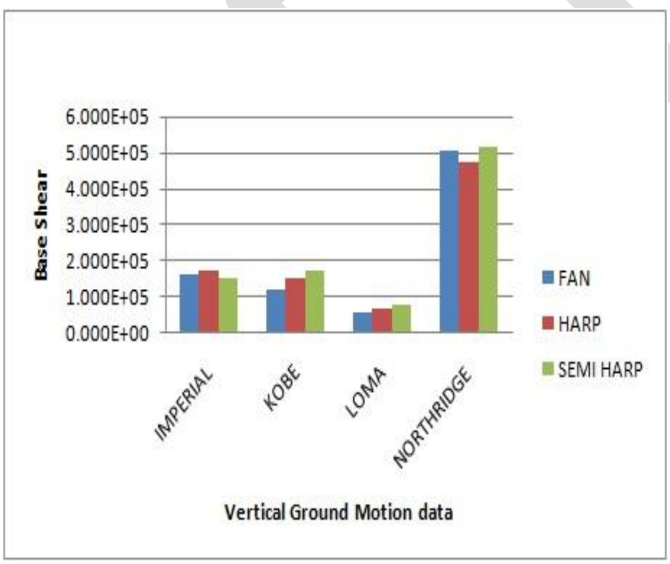
ANALYSIS

The study was conducted as two phases and in both stages non-linear time history analysis has been done using the ground motion data mentioned in Table 3.

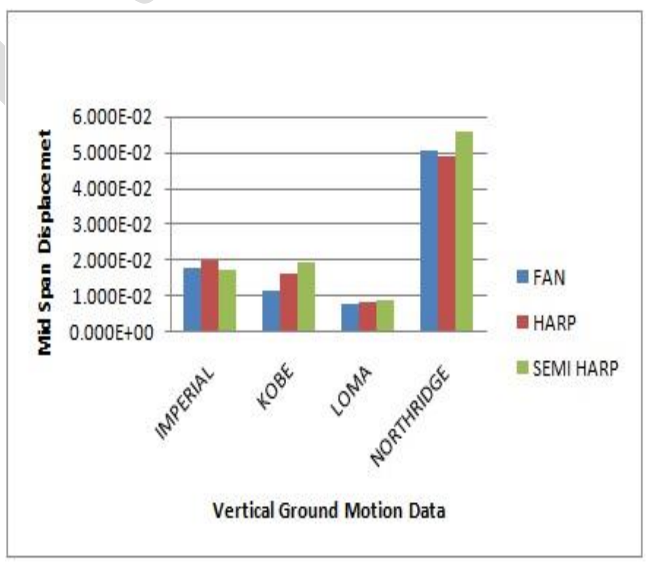
Phase 1:-

To find the best cable arrangement among Fan, Harp, Semi-Harp. The models were created in SAP 2000 with H shape pylon as constant and changing the cable arrangements. The parameters considered are base-shear, mid-span displacement, and tower - head displacement.

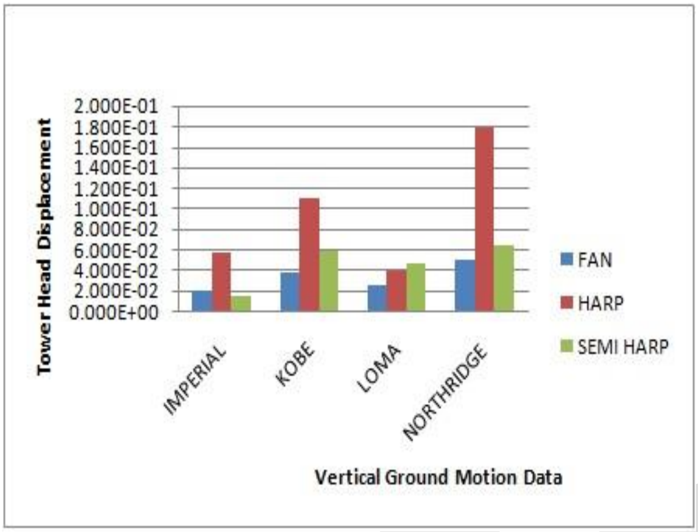
The following graphs obtained on analysing the result. The graphs shown are obtained for vertical data similar pattern are obtained while applying longitudinal and transverse data.



(a)



(b)



(c)

Fig.2. Effect of vertical ground motion data on H shape pylon with different cable arrangement (a) Base Shear (b) Mid span displacement and (c) Tower Head Displacement.

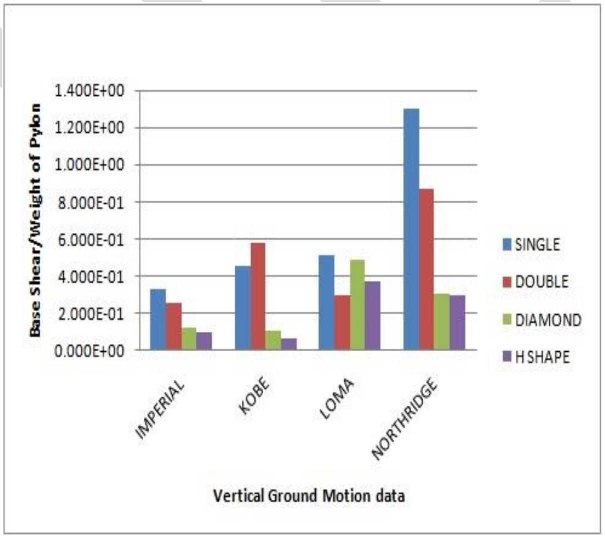
Observation:

The study based on finding the best configuration among the various layouts of cable stayed bridge was successful in finding fan sections as one of the better configuration in terms of reduced responses. Earthquake analysis which mainly concentrates base shear and displacement was found less and hence fan sections are chosen as a better configuration.

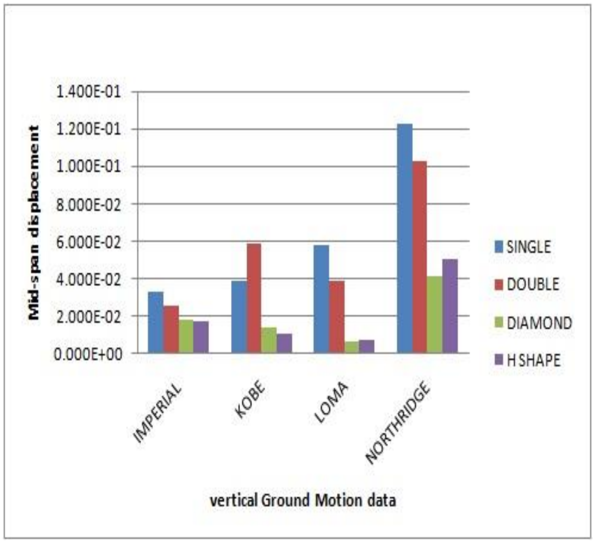
Phase 2:-

To find the best pylon shape among Single Pylon, Double Pylon, H shape Pylon and Diamond Shape Pylon with Fan shape Cable Arrangement. The models were created in SAP 2000 with Fan type cable arrangement kept constant and changing the shapes of pylon. The parameters considered are base-shear, mid-span displacement, and tower - head displacement.

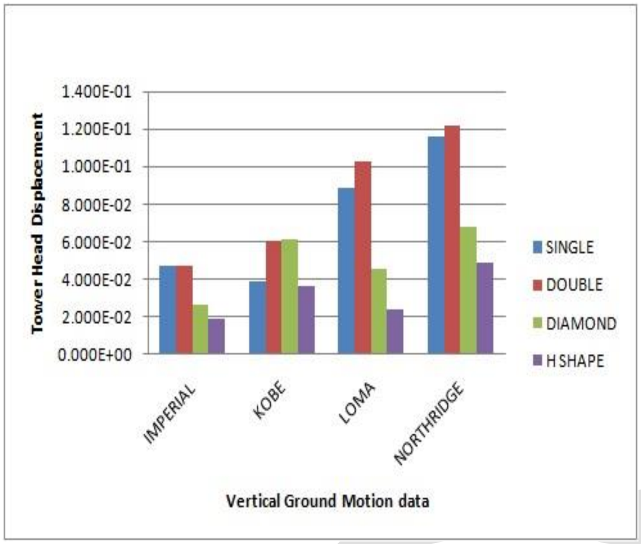
The following graphs obtained on analysing the result. The graphs shown are obtained for vertical data similar pattern are obtained while applying longitudinal and transverse data.



(a)



(b)



(c)

Fig.3. Effect of vertical ground motion data on Fan type cable arrangement with different shape of pylon (a) Base Shear (b) Mid span displacement and (c) Tower Head Displacement.

Observation:

The study based on finding the best configuration among the various shapes of pylon of cable stayed bridge was successful in finding H shape pylon as one of the better configuration in terms of reduced responses. Earthquake analysis which mainly concentrates base shear and displacement was found less and hence H shape pylons are chosen as a better configuration.

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CONCLUSIONS

In this study, the modeling of cable stayed bridge has been done for three different cable arrangement i.e. Fan, Harp, Semi-Harp with H Shape Pylon on SAP 2000 software and found that Fan arrangement gives better seismic stability. Thus, on the second stage of study four different types of pylon shapes i.e. Diamond type, H type, Double pylon type and Single pylon Type with fan type cable arrangement were modeled on SAP 2000 software. The analysis results showed that H shape pylon with Fan Type cable arrangement gives better seismic stability.

The conclusions are based on the models which were prepared using SAP 2000 software therefore; an experimental verification may be performed on these before implementing these in practice.

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