THE CRITICAL DIRECTION OF SEISMIC INPUT FOR DYNAMIC ANALYSIS OF LONG SPAN CABLE-STAYED BRIDGE

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ABSTRACT :
In dynamic analysis of a complicated structure, the critical direction of seismic input is corresponding to the maximal response of the structure. Based on MIDAS software, the response analysis of a long span cable-stayed bridge under seismic input of different directions had been conducted, the calculating results show that both structure dynamic property and the selected seismic input have effect on the critical direction of seismic input of a structure, and the long period components of ground motion should be considered in the response analysis of long span cable-stayed bridge.

KEYWORDS: cable-stayed bridge; seismic input; critical direction

1. INTRODUCTION

Bridges are key structures of transportation system. The damage of a bridge can lead to the direct economical losses and indirect effects to the society, such as the difficulty and obstacles of post earthquake emergency rescue. The materials and personals for disaster relief can not reach the disaster area in time, the wounded can not be dissipated quickly, and therefore the disaster can not be effectively controlled. With the development of economy, more and more people moved to modern cities, the society's dependence to transportation system are stronger than ever, so the influence to society and economy caused by the damage and function loss of transportation system may be serious. Long span cable-stayed bridge is widely constructed now, but the seismic safety is not very clear for less of researches. The seismic response analysis is the basis of seismic research of this kind of bridges. Normally, the seismic input of the structure can be simplified as two vectors in axial and lateral direction, but the seismic response of a structure is different while the seismic input varies, the influence of input direction to seismic response of a long span cable-stayed bridge should be considered carefully. Some experts had paid some attention to this issue, such as ALY S. NAZMY (1992), OSCAR A.LOPEZ et al (1997) and Nie Liying et al (2003). The principle and effect of critical angle of seismic input for complicated structures have been studied. Based on their achievements, the critical direction of long span cable-stayed bridge is studied by using MIDAS civil software.

2. CALCULATING MODEL AND DYNAMIC PROPERTY ANALYSIS

The seismic characteristic of a bridge is closely related to the dynamic property of the structure. The establishment of a bridge's mechanical model which can reflect the actual working state of the structure is the basis of dynamic property analysis. The establishment of mechanical model needs some reasonable abstract and simplification, but the equivalence for both the stiffness and the mass as well as their distribution of the structure should be maintained, besides, the accordance to the boundary condition is also very important.
Single beam, double beam and tri-beam model are applicable models for main beam of a cable-stayed bridge. As to single beam model, the calculation of bending resistance stiffness and axial stiffness of main beam is clear, there is no distribution problem. The twisting stiffness of box beam is mainly provided by its free twisting stiffness, the calculation of free twisting stiffness is simple, so the single beam model is generally used.
The protocol structure for analysis is a double tower double cable steel cable-stayed bridge which is 1088

meters long; the designed spans are 98,100,300,1088,300,100,98 meters respectively. the main beam is constructed with Q345q steel, the tower is constructed with C50 concrete, the cable is 1770MPa steel wire. By using the MIDAS civil software, the FEM model of the bridge is established, the main beam and tower are simulated as beam element, the cable is simulated as truss element. There are totally 1020 elements, 1037 nodes. The model is shown in figure 1. The dynamic property analysis results are listed in table 1, including the vibration periods and the related mode shapes. The first free vibration period is 13.295s, which indicates that the bridge is a structure with long period. Part of the mode shapes are shown in figure 2.

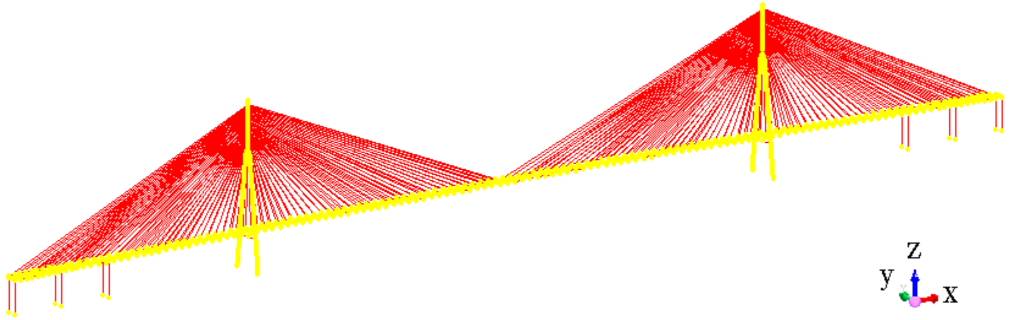
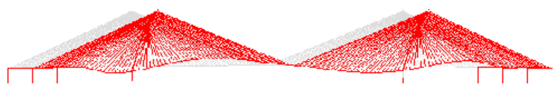


Figure 1 FEM model of the bridge

Table 1 Free vibration periods and the mode shapes

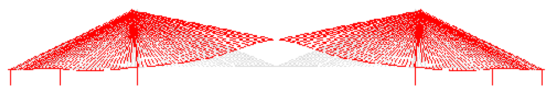
order	period/s	Mode shape
1	13.294729	Symmetry lateral bending of the main beam
2	7.676391	Longitudinal floatation
3	4.802741	Dissymmetry lateral bending
4	2.873471	Symmetry vertical bending of the main beam
5	2.528156	Symmetry lateral bending

Mode 1



Mode 2

Mode 3



Mode 4

Figure 2 The first four calculated mode shapes of the bridge model

3. EARTHQUAKE RESPONSE ANALYSIS

Three earthquake records are selected as the seismic input of the bridge when performing the seismic response analysis. The first case is El-centro ground motion with a maximum acceleration of 0.35g, and the predomination period is 0.5s. The second case is Taft ground motion with an adjusted maximum acceleration of 0.35g, and the predomination period is 0.3s. The third case is Mexico ground motion with an adjusted maximum acceleration of 0.35g, and the predomination period is 2.0s. Only two horizontal vectors of the seismic excitations are considered in the analysis. The seismic input direction varies from 0 degree to 180 degree with an interval of 10 degree. Both the deformation and the stress response of the structure are studied, and the combination stress of the tower and main beam of the bridge are investigated carefully, including the value and the distribution. The followings are analysis results of the top of left tower and the middle of main beam. Figure 3 to figure 5 show the stress of the tower and the main beam of the bridge with inputs of the three selected earthquake ground motions and typical input angle, figure 6 shows the relationship between the maximum longitudinal displacement on top of left tower to the seismic input angles, figure 7 shows the relationship between the maximum longitudinal displacement in the middle of main beam to the seismic input angles, and figure 8 shows the relationship between the maximum lateral displacement in the middle of main beam to the seismic input angles. Figure 9 is the maximal longitudinal displacement time history on top of the left tower, figure 10 is the maximal longitudinal displacement time history in the middle of the main beam, and figure 11 is the maximal lateral displacement time history in the middle of the main beam. The calculated results of combination stress and displacement are listed in table 2, the percentage of amplification of most adverse input compared with the response of axial input are listed in table 3.

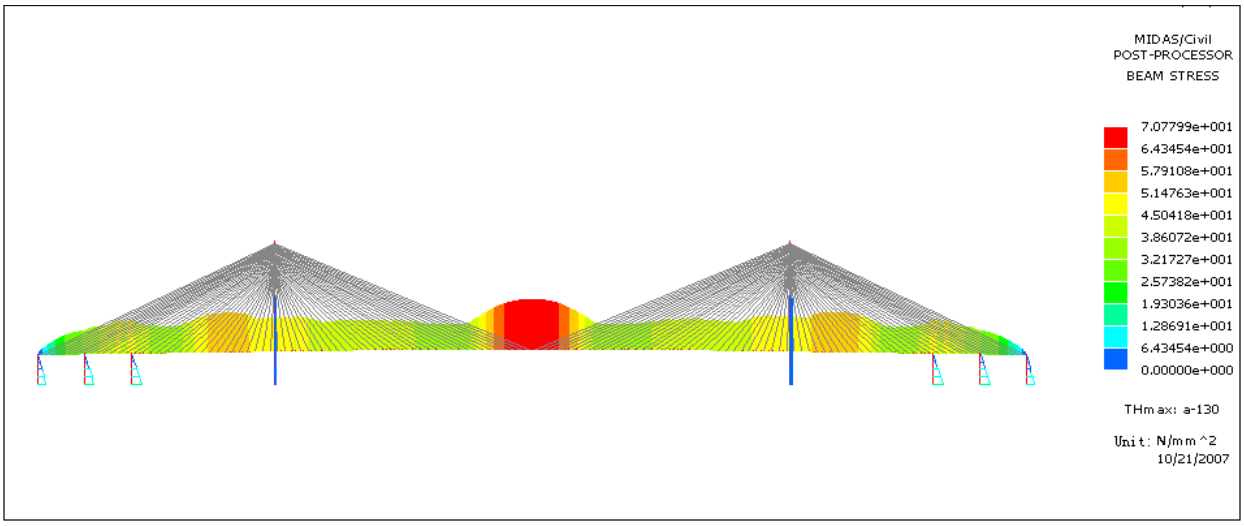


figure 3 El-centro record, input angle is130°

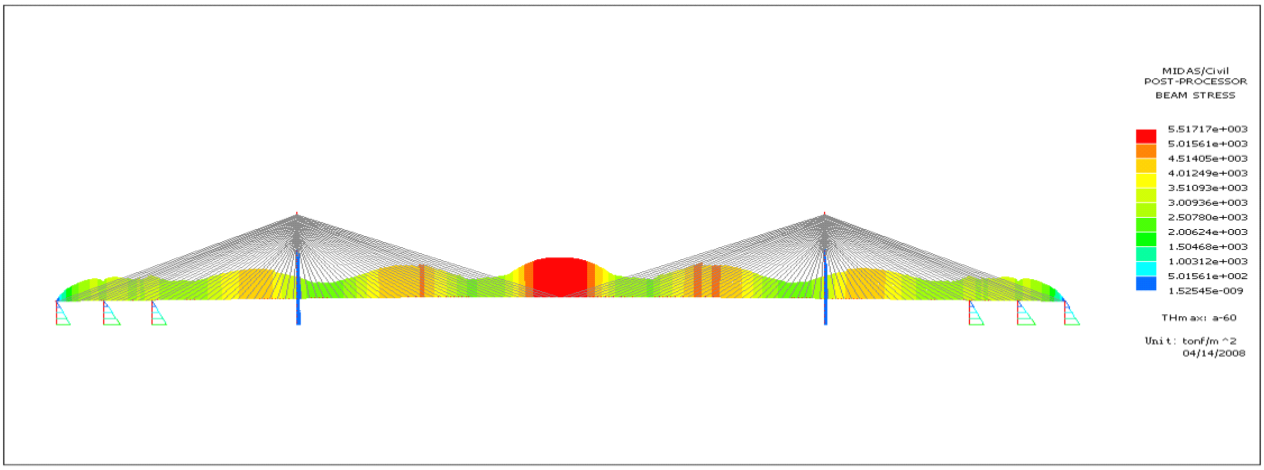


figure 4 Adjusted Taft record, input angle is60°

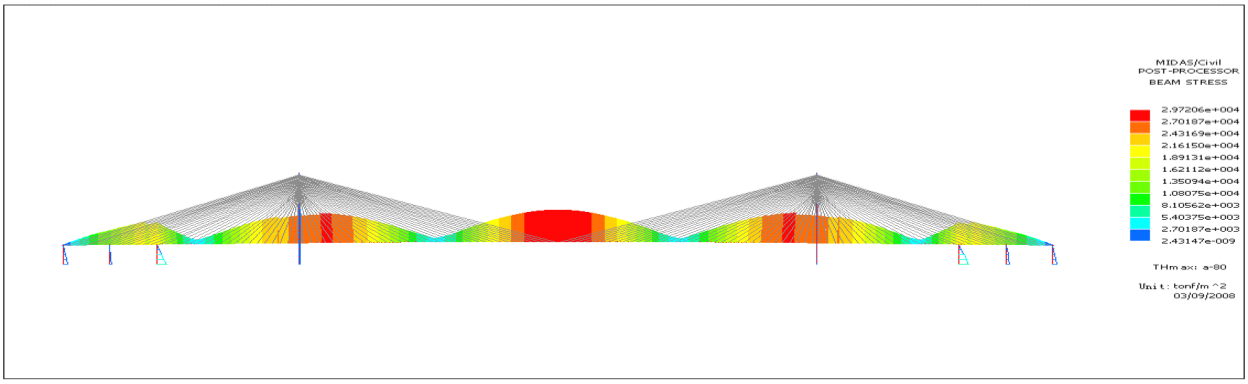
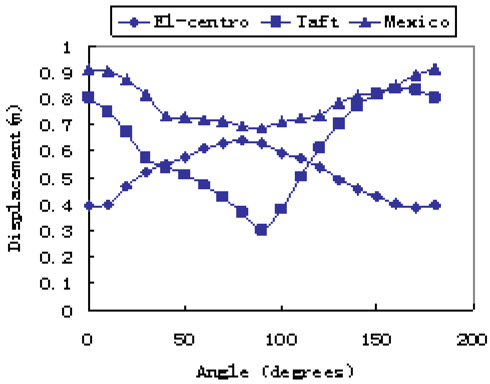


Figure 5 Adjusted Mexico record, input angle is80°



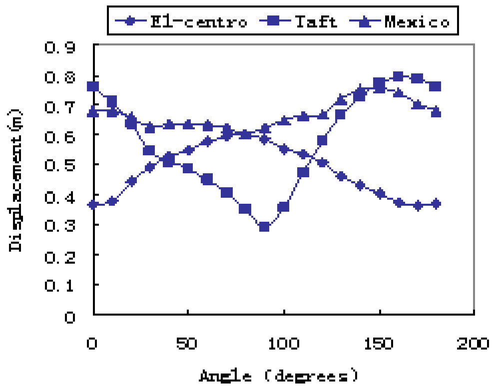
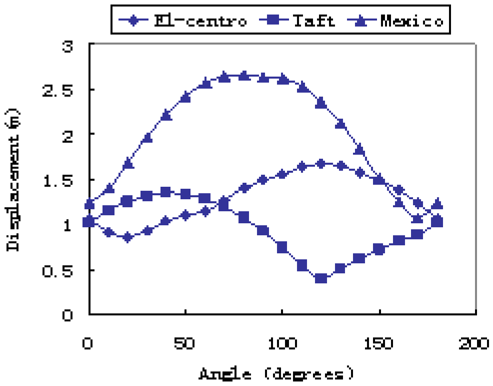


Figure 6 Longitudinal displacement on top of left tower Figure 7 maximal longitudinal displacement of main beam



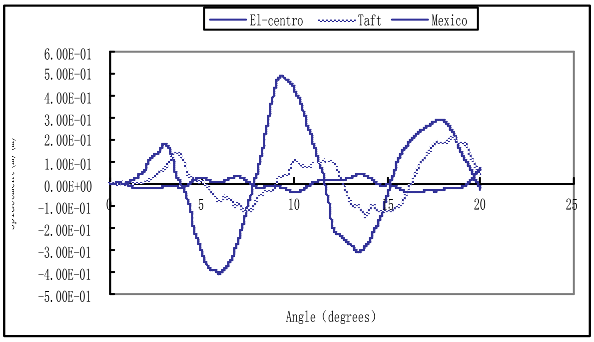
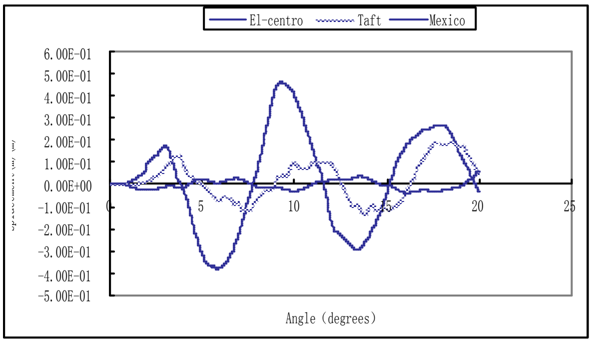
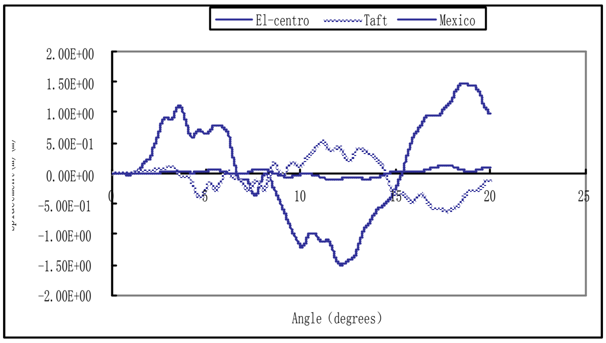


Figure8 Maximal lateral displacement of main beam Figure 9 maximal longitudinal displacements on top of the left tower Figure





10 maximal longitudinal displacements in the middle of the main beam   Figure 11 maximal lateral displacement time histories in the middle of the main beam

Table 2. Calculated results of combination stress and displacement

Case	Seismic input in axial direction				Seismic input in most adverse direction			
	Stress, middle of main besm	Longitudinal displacement on top of the left tower m	Longitudinal Displacement In the middle of main beam	Lateral displacement in the middle of main beam	Stress in the middle of main beam/Mpa	Longitudinal displacement on top of the left tower	Longitudinal Displacement In the middle of main beam	Lateral displacement in the middle of main beam
El-centro	44.8 Mpa	0.39m	0.36m	1.06m	70.7 Mpa	0.63m	0.59m	1.65m
					130° *	79.4°	76.6°	120.2°
Taft	42.5 Mpa	0.80m	0.76m	1.02m	54.1 Mpa	0.83m	0.78m	1.34m
					60°	175.3°	166.5°	40.3°
Mexico	148.8 Mpa	0.91m	0.68m	1.24m	291.5 Mpa	0.91m	0.76m	2.66m
					80°	0°	147.6°	82.9°

*: The degrees are most adverse input direction corresponding to the maximal response

Table 3 Percentage of amplification of most adverse input compared with response of axial input

Case	Stress main beam	Displacement left tower	Longitudinal Displacement middle of main beam	Lateral displacement middle of main beam
El-centro	57.8%	61.5%	63.9%	55.7%
Taft	27.3%	3.8%	2.6%	31.4%
Mexico	96%	0	11.8%	114.5%

Figure 3, figure 4 and figure 5 show that the maximal stress of main beam occurred at the middle of span in cases of El-centro and Taft excitations, as to Mexico input case, the stress near the bridge tower is also prominent. The distribution of stress is almost the same in the three analysis cases, the combination stress of bridge tower is smaller than that in the middle of the main beam. In case of Mexico motion input, the maximal combination stress in the middle of main beam is several times larger than that of the other two input cases; this is due to the longer predominant period of Mexico motion. The long period components of the seismic input have much more contributions to the response of long period structures, so the seismic input of a long period structure should contain reasonable long period components. From figure 9 to figure 11, one can find that the displacement response of El-centro input is the biggest among the three cases, and the displacement response of Taft input case and Mexico input case is similar. Results in table 3 shows that the response differences of the structure in the most adverse input directions vary from 0 to more than one hundred percent compared with the axial input case. Besides, the seismic response of the structure in the most adverse input directions is quite different with the change of seismic input.

4. CONCLUSIONS

The following conclusions and remarks can be made based on the analysis.
1. The axial input is not the most adverse case when conducting seismic response analysis of a long span cable-stayed bridge.
2. The response differences of the structure in the most adverse input directions can be more than one hundred percent larger compared with the axial input case. The seismic input direction of a long span cable-stayed bridge should be investigated carefully when performing seismic response analysis or seismic design.
3. The long period components of the seismic input have much more contributions to the response of long span cable-stayed bridge, so the seismic input of this kind of structures should contain reasonable long period components.

ACKNOWLEDGEMENTS

This research was supported by Grants No. 2007A02 from the Basic Science Research Foundation of the Institute of Engineering Mechanics, CEA, and the support is greatly appreciated.

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