Parametric Evaluation of Cable Stayed Bridges with Dynamic Push-Over Analysis

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Abstract

Incremental Dynamic Analysis (IDA) is a parametric analysis method that has recently emerged in several different forms to estimate more thoroughly structural performance under seismic loads. It involves subjecting a structural model to one (or more) ground motion records, each scaled to multiple levels of intensity, thus producing one (or more) curves of response parameterized versus intensity level.

This paper tries to evaluate and compare the seismic behavior of three different cable layouts; namely harp, semi-harp and fan type. For this aim, three cable stayed bridges are modeled and analyzed using nonlinear method by SAP2000 and then, the abovementioned curves are produced.

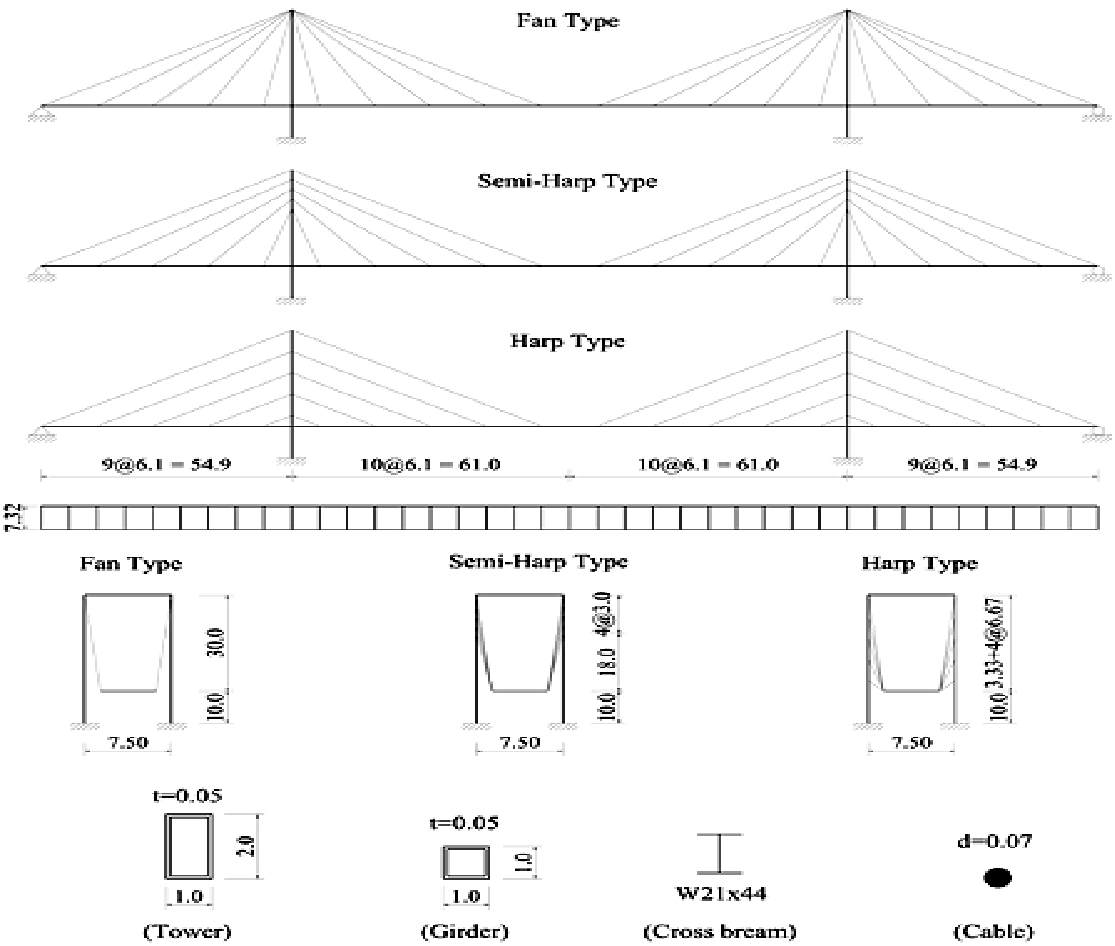
Key words: Cable stayed bridge, Incremental dynamic analysis ,Nonlinear

1. Introduction

Fleming and Egeseli (1980) performed the seismic behavior of two-dimensional cable-stayed bridges, In 1990's, The 3D nonlinear seismic response analysis of cable-stayed bridge was studied by Aly S. Nazmy and Ahmed M. Abdel-ghaffar (1990). In that paper the author paid more attention to the geometric nonlinearities, such as cable-sag effect, axial force-bending moment interaction and the large displacements. With the development of the computer science, more possible effects of nonlinearities can be included in the analysis. for instance, Wei-Xin Ren (1999) has considered the material nonlinearity due to the stiffening steel girder yielding. Kazuo Endo,(2004)and Shehata Eldabie Abdel Raheem (2003) have done some researches at the tower considering the material nonlinearity Cho and Song (2006)evaluated the global system response of a bridge using the finite element method. In their researches the steel tower was modeled by shell and fiber elements, the strength and damage progress characteristics were obtained, and the acceptable ductility capacity for the steel tower structure exceeding the elastic limit was proposed. The purpose of this paper tries to evaluate and compare the seismic behavior of three different cable layouts; namely harp, semi-harp and fan type. For this aim, three cable stayed bridges are modeled and analyzed using nonlinear method by SAP2000 and then, the abovementioned curves are produced. On the other hand, the incremental dynamic analysis (IDA) which was carried out by Dimitrios Vamvatsikos and Allin Cornell (2003) gave us a good thought to study the structure performance under seismic loads, especially for the nonlinear model, which can't be predicted well by nonlinear static pushover analysis. Therefore, in this paper the cross beam, girder, and tower members of the bridges are modelled using the frame element inSAP2000 elements.

2. Data and Material

The three-dimensional modeling of the cable-stayed bridges taken from Song and Kim (2007) is shown in (Fig.1) The girders with the central span length of 122 m are supported by a series of cables aligned in fan, semi-harp, and harp type bridges. The stress-strain



curve for the cross beam, girder, and tower members is assumed to be elastic-perfectly plastic with an initial elastic modulus of 207 GPa and a yield stress of 248 MPa. The cable members should be valid in the elastic limit of the material, with an elastic modulus of 158.6 GPa and a yield stress of 1103 MPa. The weight per unit volume of the cable and cross beam, girder, and tower members is 60.5 kN/m3 and 76.82 kN/m3 respectively.

Fig 1: Cable-stayed bridges (unit: m)

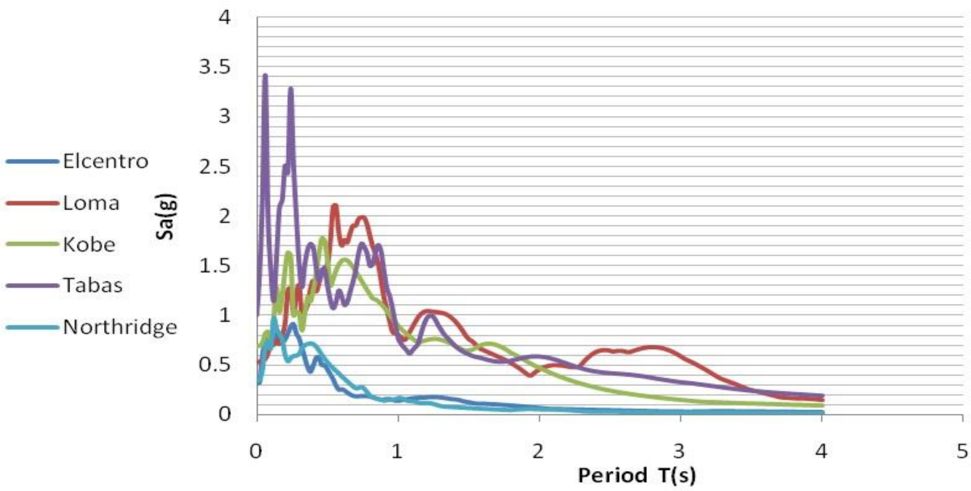
3. **Research Methodology**

This section is focused on the verification of the proposed with SAP2000 in predicting the nonlinear elastic seismic behavior of the cable-stayed bridges. The crossbeam, girder, and tower members of the bridges are modeled using the frame element in SAP2000. The cables are modeled by using the cable elements in SAP2000. responses at point of the top tower of the bridges subjected to different earthquake loadings of the El-Centro and Loma Prieta and kobe and Tabas and Northridge are shown in Table1 respectively.

To investigate the seismic behavior of the bridges, five ground motion records have been adopted, which are taken out from the pacific earthquake engineering research center (PEER) national ground acceleration (NGA) database. elastic acceleration response spectra of the five waves can be seen in (Fig. 2) other hand, for IDA analysis, recent researches have shown that taking the Sa(T1,ξ) as an Intensity Measure(IM) for scaling, can be more effective than PGA as an IM, in reducing the dispersion of the seismic response of the structure. Therefore, for this study the Sa (T1, 0.05) has been scaled from 0.005g to 0.335g, and the incremental step of 0.05g is adopted. For evaluating the displacements maximum of the top tower, are recorded during every time history analysis. seismic responses excited by wave1, wave2, wave3, wave4, wave5 are shown in Table.1.

No	Record	magnitude	soil	PGA (g)	PGV (cm/s)	PGD(cm)
1	ELCENTRO	-------------------------------	B	0.319	38	29
2	LOMAP/CAP000	M (6.9) Ml ( ) Ms (7.1)	C	0.529	36.5	9.11
3	KOBE/TAZ000	M (6.9) Ml ( ) Ms ( )	D	0.693	68.3	26.65
4	TABAS/TAB-LNB	M (7.4) Ml (7.7) Ms (7.4)	B	0.836	97.8	36.92
5	NORTHR/ARL090	M (6.7) Ml (6.6) Ms (6.7)	C	0.344	40.6	15.04

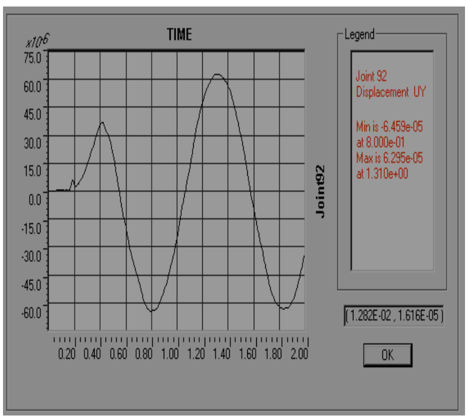
Table1. Ground motion records used for IDA analysis



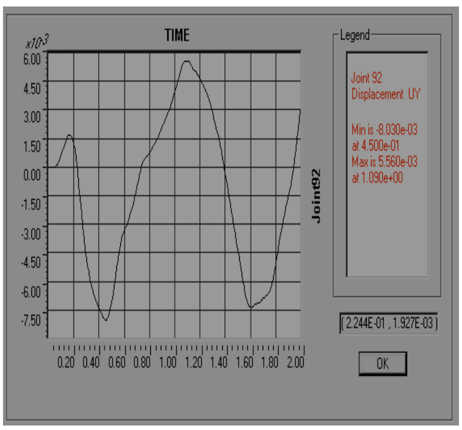
4. **Fig 2:** Elastic response spectra of the five ground motion records

5. Results and Analysis

For example the displacement responses at the top point tower of the bridges subjected to One earthquake loadings of the El-Centro are shown in (Figs. 3 and 4 and 5), respectively. The longitudinal displacement distribution of the tower at the disp. Time obtained by SAP2000 and the peak Longitudinal displacements at the point of the top tower of the bridges with three different cable layouts of fan, semi-harp, and harp type are also presented in (Fig.1) difference of displacement response of nonlinear elastic seismic analysis in tow records 0.005g and 0.355g are shown. All results obtained bySAP2000.

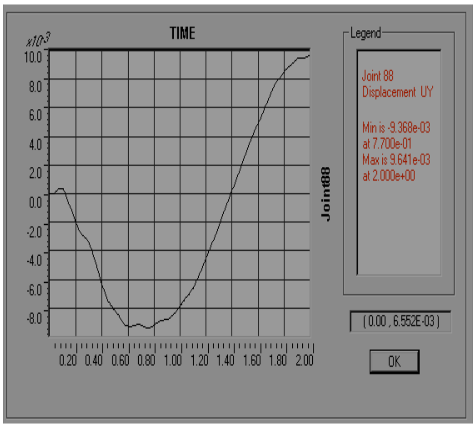


R.C (0.005g)

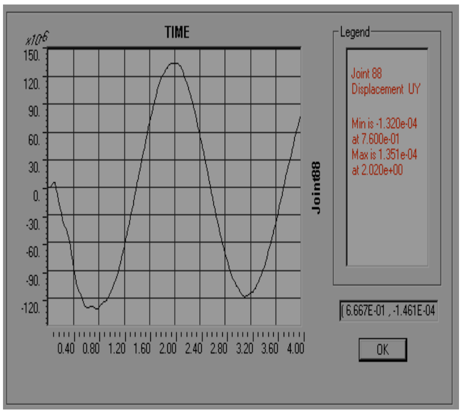


R.C (0.355g)

Fig 3: fan type

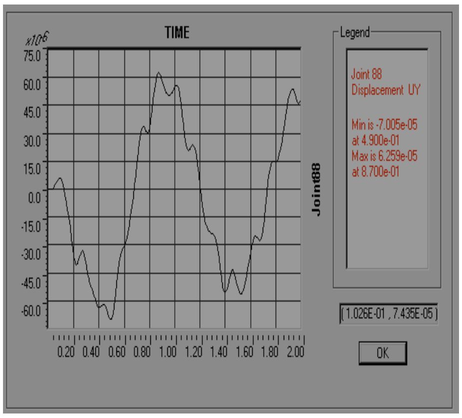


R.C (0.005g)

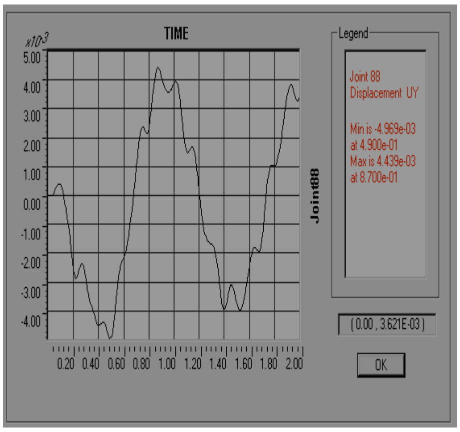


R.C (0.355g)

Fig 4: Harp typ



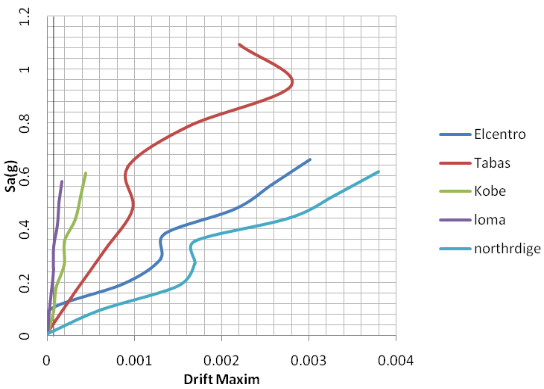
R.C (0.005g)



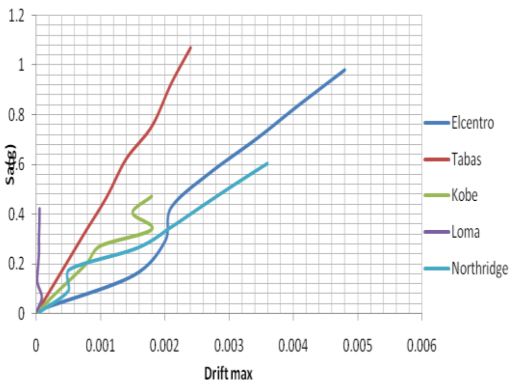
R.C (0.355g)

Fig 5: Semi Harp type

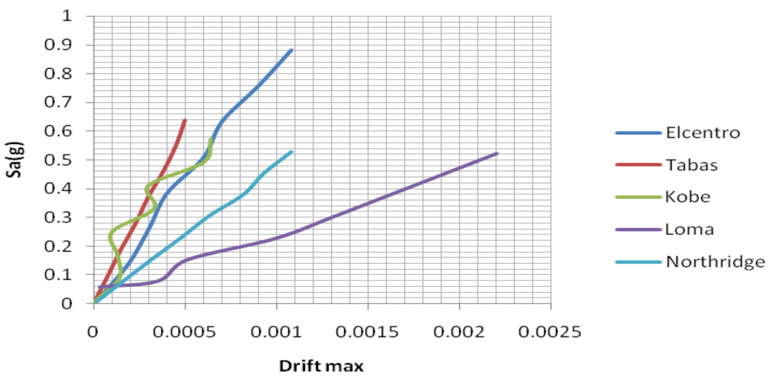
Then IDA curves of the Maximum drift ratios of the bridges with three different cable lay-outs of fan, semi-harp, and harp type are presented in **(**Fig.6)



Semi Harp type



fan type



Harp type

Fig 6: Summary of IDA curves of the Maximum drift ratios

5. Conclusions

From all the IDA analyses of the cable-stayed bridges in above, nonlinear seismic demand investigated, some conclusions can be drew as follows:

1. As the increasing of the seismic intensity, either for curvature or for displacement of the critical point of the three different cable layouts of fan, semi-harp, and harp type, the dispersion grows larger.
2. The IDA method is a precise tool for seismic damage state evaluation which has more probabilistic characteristic.
3. From the fan type and semi harp, when Sa is below 0. 1g, the tower will keep in small nonlinear, in harp type when Sa up.01g will keep small nonlinear still.
4. From the harp type is very stiffing. ductility capacity is very small to result frequency height.
5. From the fan type and semi harp ductility capacity to result frequency low.

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References

Aly S. Nazmy, Ahmed m. Abdel-Ghaffar. (1990) Non-linear earthquake-response analysis of long-span cable-stayed bridge: theory, Earthquake Engineering & Structural Dynamics.

Aly S. Nazmy, and Abdel-Ghaffar, A. M. (1990). "Three-dimensional nonlinear static analysis of cable-stayed bridges." Computers & Structures 34 (2), pp. 257-271.

Ahmed Ghobarah, Performance-based design in earthquake engineering: state of development. (2001) Engineering Structures 23, 878–884.

Chopra, A. K. (2001). Dynamics of structures: Theory and applications to earthquake engineering, Prentice Hall, New Jersey.

Chen, W. F., Kim, S. E. and Choi, S. H. (2001). "Practical second-order inelastic analysis for three-dimensional steel frames." Steel Structures 1 (3), pp. 213-223.

Kim, S. E., Kim, K. M. and Chen, W. F. (2000). "Improved refined plastic hinge analysis accounting for strain reversal." Engineering Structures 22 (1), pp. 15-25.

Kazuo ENDO, Chihiro KAWATOH, Shigeki UNJOH. (2004) Analytical Study On Seismic Performance Evaluation Of Long-Span Suspension Bridge Steel Tower, 13th World conference on earthquake engineering Vancouver, B.C., Canada, No.944.
.

W.-X. Ren and M. Obata. (1997) Elastic-Plastic Seismic Behavior Of Long Span cable-Stayed Bridges, Journal of Bridge Engineering, ASCE, 4: 3,194-203.

YAN Haiquan WANG Junjie. (2007) A tower model for seismic response prediction of floating cable-stayed bridge in longitudinal direction. Journal Of Earthquake Engineering And Engineering Vibration 27:4 80-86.