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Effect of Multi-Support Excitation on Cable-Stayed Bridge and Cable-Stayed Suspension Hybrid Bridge

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Abstract: *The cable-stayed suspension hybrid bridge (CSSHB) is combination of two structural systems one is cable-stayed bridge, which provide more rigidity due to presence of tensed cable stays as a force resistance element and another is suspension bridge, which provide more span in bridge. So, combination of these two systems can be used to provide more span in bridge. In this study, effect of multi-support excitations is introduced in cable-stayed bridge and cable-stayed suspension hybrid bridge (CSSHB) and also analysed using non-linear time history in SAP2000 software. A comparison is made with cable-stayed bridge with effect of multi-support excitation and the hybrid bridge with effect of multi-support excitation and found that the acceleration of deck, displacement of deck and top pylon displacement and compared to with multi-support excitation on cable-stayed bridge and cable-stayed suspension hybrid bridge (CSSHB).*

Keywords: *Cable-stayed bridge, Suspension bridge, Cable-stayed suspension hybrid bridge, Multi-support excitation, SAP2000*

I. INTRODUCTION

The function of bridge is to travel across large spans of land or largest mass of water, and to connect two far-off points, after all reducing the distance between them. The bridge design is depending on the nature of the land and the use of the bridge and also depends on the construction area of the bridge. There are different types of bridge are available like cable stayed bridge, beam bridge, truss bridge, arch bridge, etc. In suspension bridge, cables are providing between towers and that cables are known as suspension cables and also provide vertical cables or suspender cables are known as hangers that hold the deck. These cables are always in tension and carry the majority load and transfer the load on pylon. The idea of using chain or rope to support a bridge span will result in to the new attraction which is known as cable stayed bridge. The cable styed bridge is similar to suspension bridge. In this type of bridge, towers and deck are hold by cables, but its cables hold the deck connecting it directly to the towers instead via suspender cables. Now days, suspension and cable-stayed bridge are used for larger span bridge. cable-stayed bridge possess high rigidity tensioned cable whereas suspension bridge gives larger span. The bridge which will be constructed combining above two bridge will have longer span and higher stiffness and that type of bridge is known as Cable-Stayed Suspension Hybrid bridge (CSSHB).

A. Multi-Support Excitation

It is important to perform dynamic analysis for the structures subjected to earthquake induced ground motions. The support induced vibrations cause deformations and stresses in the structural systems. There are two types of support excitations such as single-support excitation and multi-support excitation. In single-support excitation, the same ground motion is considered at all supports point of a bridge such as pier and pylon of bridge. The supports move as one rigid base. The presence of spatial variation in ground motion leads to the different excitation at different support points of a bridge such as pier and pylon of the bridge which is known as multi-support excitation (MSE).

II. LITERATURE REVIEW

Palheriya and Dabhekar [1] presented state-of-the review on the analysis of the CSSHB.

Zhang et al. [2] carried out three-dimensional nonlinear aerodynamic stability analysis of cable stayed suspension hybrid bridge of 1400m span. They also carried out parametric study to find the influence of various design parameters on the aerodynamic stability of the bridge are analytically investigated.

Savaliya et al. [3] studied the nonlinear static analysis and modal time history analysis of cable-stayed suspension hybrid bridge in SAP2000 software. The time period of bridge for different mode shape were also presented.

Kartal and Soyluk [4] studied the effect of multi-support earthquake ground motions and traffic loadings on the dynamic behaviour of a cable-stayed bridge. The results showed that the structural responses obtained for the multi-support earthquake excitation are usually larger than the responses determined for the traffic loading. They concluded that the combined effect of the multi-support earthquake ground motions and traffic loadings should be considered for the realistic design of cable-stayed bridges. Li and Yang [5] investigated effects of multi-support excitation on seismic response of a long span prestressed concrete continuous rigid frame bridge. They considered local effect, passage effect as well as incoherence effect and in numerical simulation. They concluded that uniform seismic excitation is not able to control the seismic design for long span rigid framed bridge and influence of multi-support excitation must be considered for the rigid framed bridge.

Patel et al. [6] investigated response of TFPS-isolated cable-stayed bridge with multi-support excitation using SAP2000. They concluded that base shear and deck acceleration reduced and bearing displacement is increased under the MSE as compared to without MSE.

III. OBJECTIVES OF PRESENT STUDY

- A. To model CSB and CSSHB using SAP2000.
- B. To Model of CSSHB with shape of pylon as delta using SAP2000 to study effects of multi-support excitation in the bridge.
- C. To compare response of CSB and CSSHB with multi-support excitation.
- D. To accomplish parametric study in order to find influence of various parameters like displacement, acceleration and top pylon displacement on the seismic response of bridge with multi-support excitation.

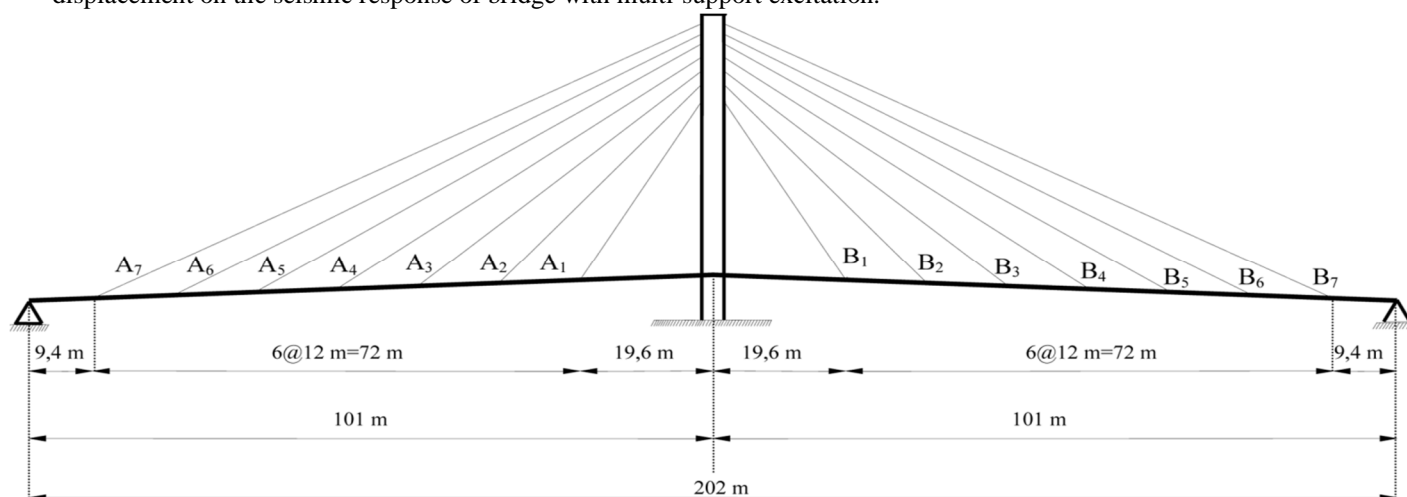


Figure 1. Schematic diagram of Manavgat Cable Stayed Bridge

IV. BRIDGE CONFIGURATIONS

The bridge configuration is based on cable-stayed bridge and cable-stayed suspension hybrid bridge. In this study, the cable bridge is selected for numerical study. This cable bridge is as same as the bridge constructed in Turkey, Atmaca and Ates (2012). The bridge is divided into two equal spans. Cross section area of the bridge tower is hollow hexagonal. Composite section is used for deck of bridge which consists of 25 cm thick concrete, 10 cm thick asphalt. 28 no. of cables are used to support the deck which are tie-up to tower. I cross section steel girder is used in deck from one end to another end of the bridge. Distance between the pylon and nearest cable is 19.6 m and distance between abutment and nearest cable is 9.4 m. Distance between intermediate cable is 12 m. Pylon is rested on the 1 m thick concrete base and effect of MSE is also investigated. The geometric configuration of CSB is shown in Figure 1. The description of the bridge is given below.

- 1) *Bridge:* Manavgat cable stayed bridge
- 2) *Location:* Turkey
- 3) *Span Length:* 202 m
- 4) *Pylon Height:* 42 m
- 5) *Pylon Shape:* Inverted Y-shape
- 6) *C/s of Pylon:* $2.128 \times 2.850 \text{ m}^2$
- 7) *Elastic Modulus (strand):* $1.97 \times 10^5 \text{ kN/m}^2$

The bridge configuration is based on cable-stayed suspension hybrid bridge of Ling Ding Strait in China having pylon height 258.9 m, two side spans = 319 m and central span is 1400 m. The behaviour of hybrid bridge is studied for delta-shaped pylon and effect of MSE is also investigated. The geometric configuration of CSSHB is shown in Figure 2.

Geometrical details:

- A. Main span = 1400 m
- B. Side Span = 319 m
- C. Height of Pylon = 258.9 m
- D. Dimension of tower's column = $6 \times 5 \text{ m}$
- E. Transverse beam = $3.17 \times 3.17 \text{ m}$
- F. Girders = 36.8 m wide, 3.494 m high

Table 1 Member Details

Members	E (MPa)	A (m^2)
Tower C	3.8×10^7	30
Tower TB	3.8×10^7	10
Main Cable CS	2×10^5	0.3167
Main Cable SS	2×10^5	0.3547
Hanger Cable	2×10^5	0.0064
Stayed cables	2×10^5	0.31

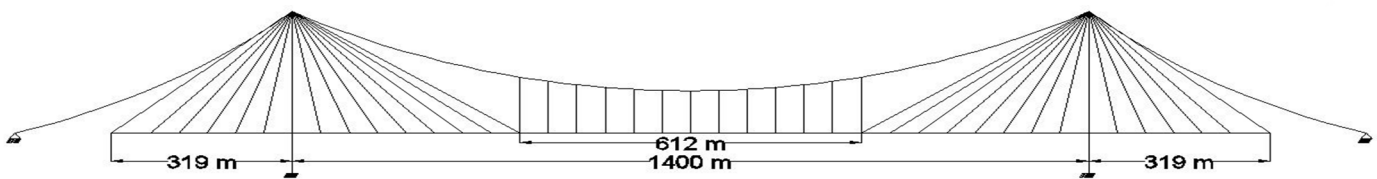


Figure 2. Schematic diagram of Cable Stayed suspension hybrid Bridge

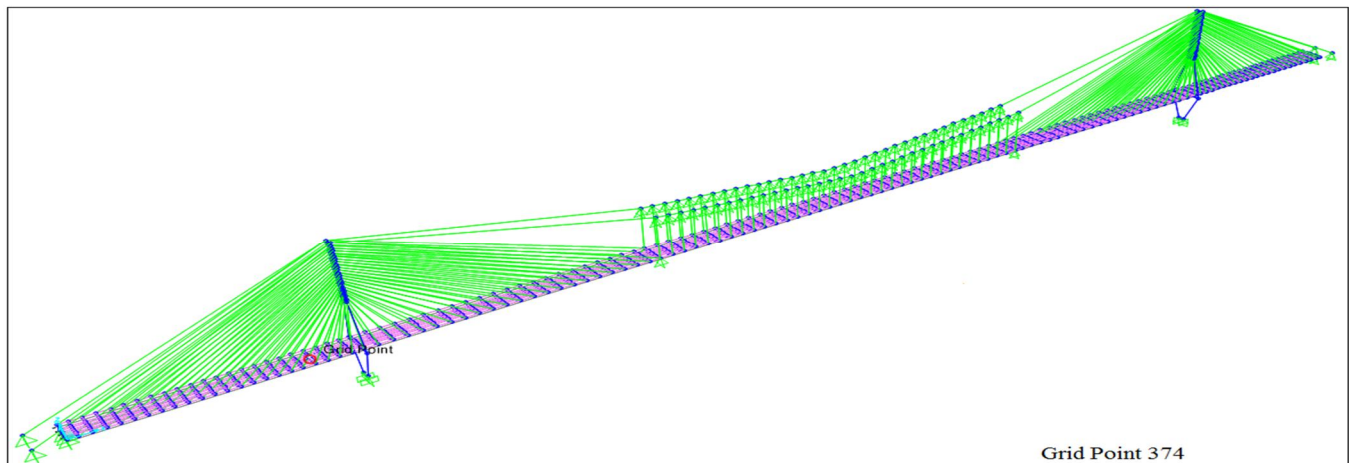


Figure 3. 3D view of CSSHB

V. ANALYSIS OF CSB AND HYBRID BRIDGE

Nonlinear dynamic analysis is carried out to determine response of the cable-stay bridge and CSSHB with MSE. The near fault ground motions used in the study are shown in Table. The repose quantities of interest are deck displacement, deck acceleration & top pylon displacement. The N-S component of earthquake is applied in longitudinal direction of the bridge. Table 3 shows the Peak ground acceleration (PGA), Peak ground velocity (PGV) and Peak ground displacement (PGD) of near-fault ground motions.

Table 2 Ground Motion Data

Earthquake	Recording station	PGA (g)	PGV (m/sec)	PGD (m)
Imperial Valley, 1979	El Centro Array #5	0.37	0.98	0.765
Imperial Valley, 1979	El Centro Array #6	0.46	1.13	0.491
Northridge, 1994	Newhall	0.72	1.19	0.381
Northridge, 1994	Sylmar	31.1	122	0.73

Figures 4 show comparison of deck displacement of CSB and CSSHB with MSE.

Figures 5 show comparison of deck acceleration of CSB and CSSHB with MSE.

Figures 6 show comparison of top pylon displacement of CSB and CSSHB with MSE.

From the Figures 4-6, it is observed that all response quantities of interest are increased in case of CSSHB with MSE. Therefore, influence of multi-support excitation must be considered for the analysis of CSSHB.

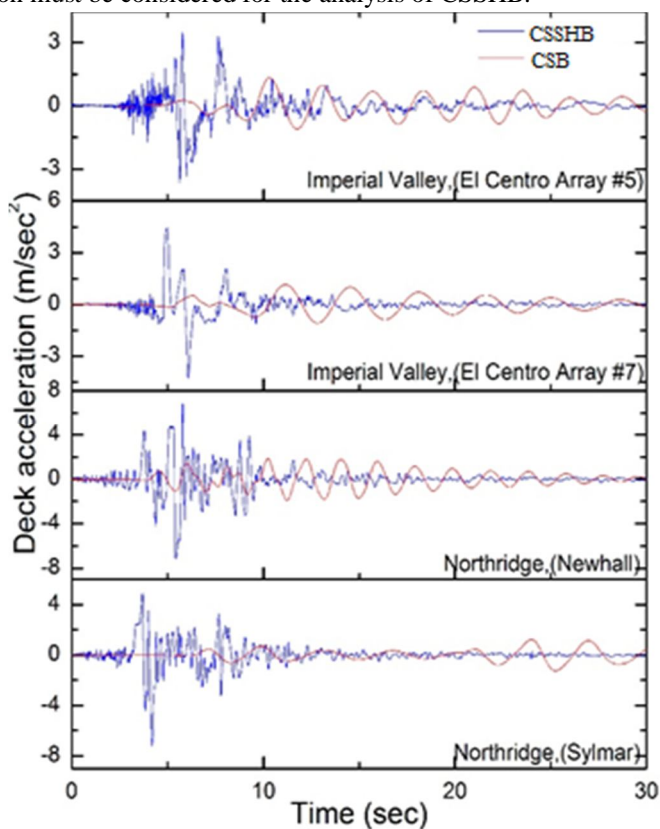


Figure 4. Comparison of deck acceleration

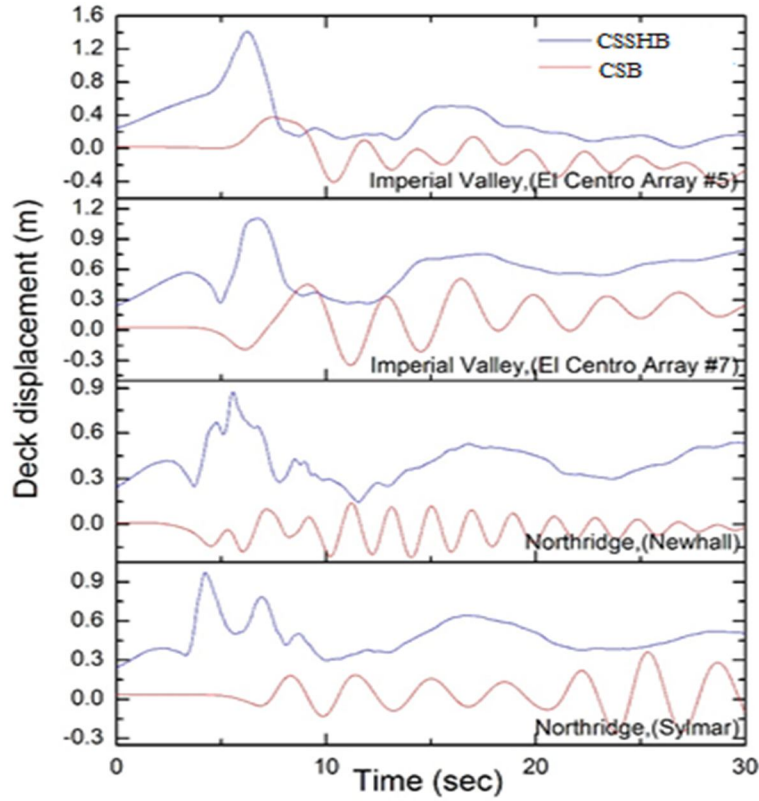


Figure 5. Comparison of deck displacement

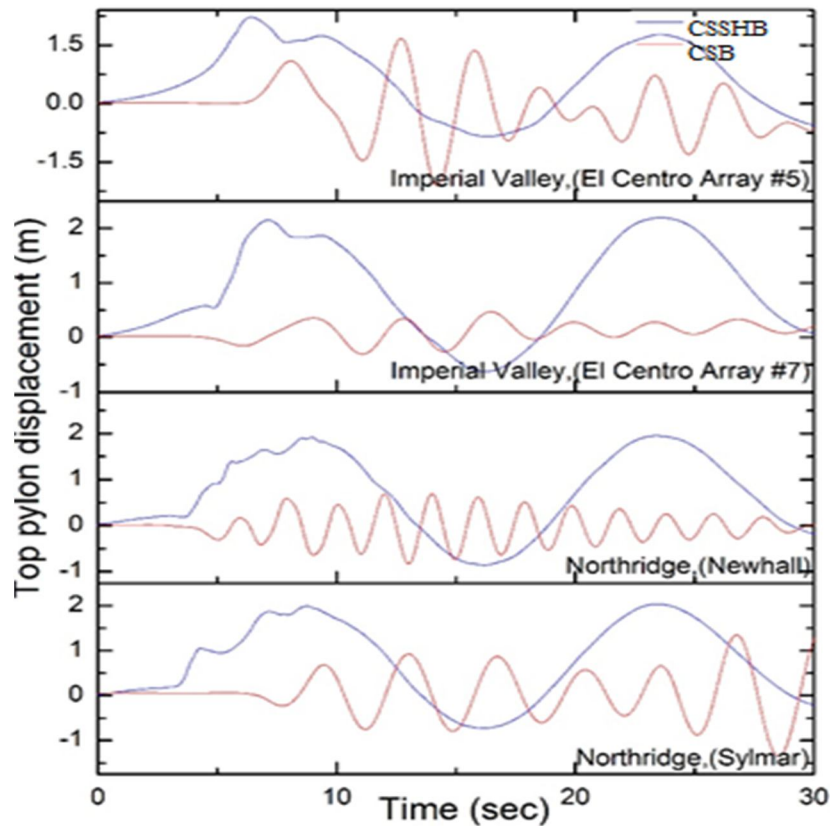


Figure 6. Comparison of top pylon displacement

Table 3 Peck Response Quantities of CSSHB and CSB

Near-fault earthquake ground motion	Deck displacement (m) (Grid point 374)		Deck acceleration (m/sec ²) (Grid point 374)		Top pylon displacement (m) (Grid point 1253)	
	CSSHB	CSB	CSSHB	CSB	CSSHB	CSB
Imperial Valley, 1979 (El Centro #5)	1.52	0.521	2.50	1.30	2.56	1.054
Imperial Valley, 1979 (El Centro #7)	1.24	0.685	3.57	1.05	2.20	1.07
Northridge, 1994 (Newhall)	0.95	0.503	6.73	2.19	2.05	1.047
Northridge, 1994 (Sylmar)	1.271	0.671	5.02	2.64	2.43	1.57

VI. CONCLUSIONS

In this study, seismic response of cable-stayed bridge and cable-stayed suspension hybrid bridge (CSSHB) using multi-support excitation has been investigated using SAP2000. On the basis of results following conclusions may be drawn:

- A. Deck displacement of cable-stayed bridge with multi-support excitation is less than that of CSSHB with multi-support excitation.
- B. It is observed that deck acceleration of cable-stayed bridge with multi-support excitation is less than that of CSSHB with multi-support excitation.
- C. It is also concluded that top pylon displacement of cable-stayed bridge is reduced for multi-support excitation as compared to CSSHB with multi-support excitation.
- D. As uniform seismic excitation is not able to control the seismic analysis of long span hybrid bridge, influence of multi-support excitation must be considered for the analysis of CSSHB.

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