SEISMIC ANALYSIS OF JIUJIAPENG BRIDGE UNDER EXCITATION OF TRAVELLING WAVE

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ABSTRACT :

Earthquake excitation input is an important focus in the seismic analysis. For long span bridge, the traveling wave effect should be taken into consideration. To study the traveling wave effect on long span concrete box girder, the finite element analysis is performed on Jiujiapeng Bridge. In the analysis procedure, the bridge construction process is modeled to consider the exact internal member force distribution. The box girder response under both the coincident earthquake excitation and multi-support seismic excitation is also analyzed. The analysis result shows that the bridge seismic response under multi-support seismic excitation is much different from that under consistent seismic excitation. Some useful results are drawn for the bridge aseismic assessment.

KEYWORDS: seismic analysis, box girder, traveling wave, finite element

1 INTRODUCTION

The seismic spatial effect should be considered in the seismic response for the long-span spatial structures, as a result that the supports move un-uniformly under seismic excitation. Due to the uncertainty of the earthquake occurrence and the complexity of the earthquake wave propagation, the randomness and the spatial variation of the ground vibration caused by the earthquake should be taken into consideration when the aseismic design for the long span bridge is performed in practice[1, 2]. The seismic input is assumed as the consistent seismic input for structural seismic analysis in the conventional aseismic analysis. For the long span spatial structure, the spatial variation effect for seismic input should be considered appropriately. It is important to determine the seismic input for long span spatial structures. The energy released from the earthquake source is transited in the seismic wave propagation form, which induces the ground vibration. The seismic wave received at different locations on the ground may travel through different path, different ground geography and different geological stratum, which in turn gives rise to different ground vibrations. Even if the other conditions are the same for two different ground locations, there exists time lag between ground seismic waves received at those two locations due to the fact that the distances between the ground location and the earthquake source center are not the same. According to the earthquake seismic monitoring results, there exists ground vibration variation. Especially for long span spatial structures, the ground vibration variation should be considered appropriately to consider the unfavorable loading condition. As a case for study, the seismic analysis of Jiujiapeng Bridge under multi-support seismic input is performed to investigate the internal force time-history result for aseismic assessment.

2 MODAL ANALYSIS

2.1 Structure Layout of Jiujiapeng Bridge

JIujiapeng Bridge is a rigid continuous bridge located in Sichuan Province with total span of 254.60m. The bridge layout is the rigid continuous prestressed concrete box girder. The layout of the bridge is shown in Figure 1. The single box with single room is adopted in the main girder. The double direction prestress concrete box girder section is used. The bridge piers are made up of rectangular hollow thin-walled concrete piers. The transverse width of the top pier is 5.0m with 50:1 inclination slope in the other two sides direction. The transverse width of the bottom pier is 8.0m with wall thickness of 1.20m. The deep pile foundation is made up of 6 bored cast concrete piles with length of 2.5m. The C50 concrete is used for the bridge box girder construction material and C40 concrete is used for the bridge pier construction material. The C30 concrete is used for the bridge pier cover beam, bridge pile foundation construction.

The double direction prestress tendon is used to reinforce the box girder. The design load for the bridge is Highway-II type according to China Bridge General Design Code(JTG D60-2004).

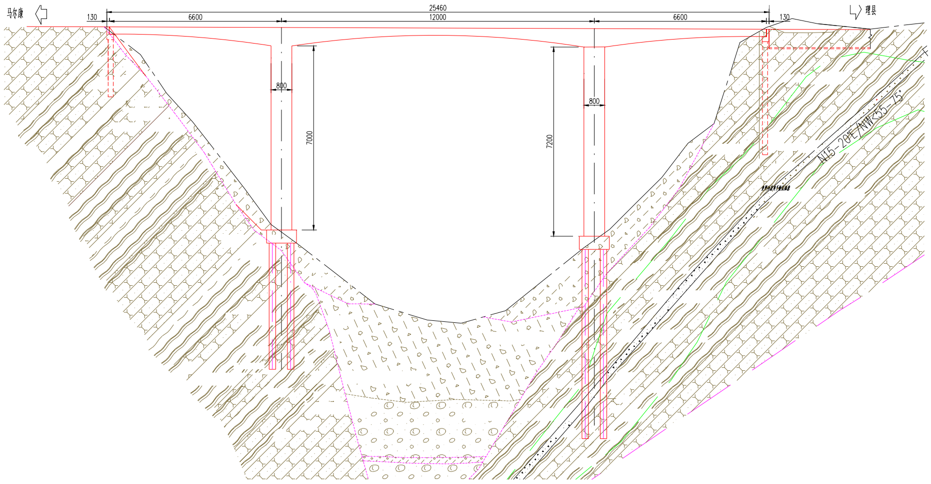
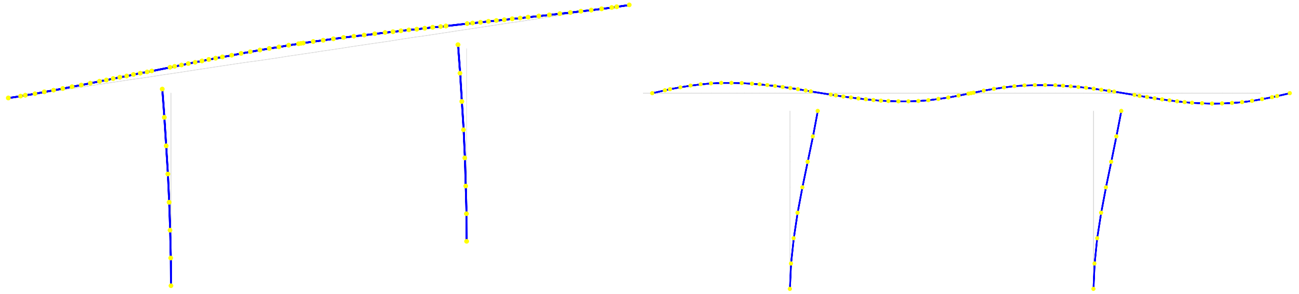


Figure 1 Planar layout for Jiujiapeng Bridge

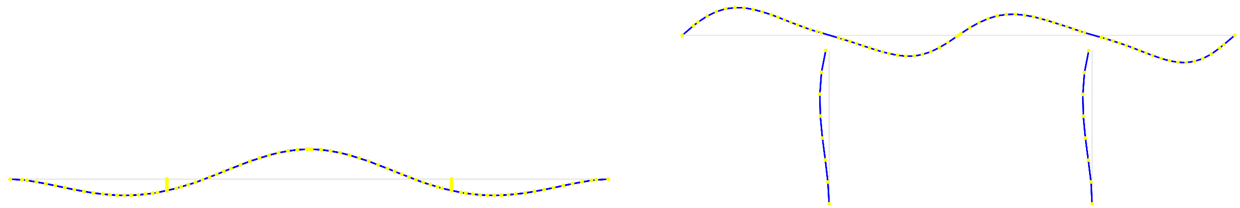
2.3 Modal Analysis of Jiujiapeng Bridge

The three dimensional taper beam is used to model the box girder. In the finite element model, 86 spatial beam elements are used to model the Jiujiapeng Bridge box girder and the bridge piers. The pile foundation is thought to be rigid. The side support for the bridge is taken as simply supported with free longitudinal movement. The prestress tendon is carefully modeled with the exact spatial shape using the embedded truss element. The subspace iteration method [3] is used to extract the first 10 modal shapes of the bridge, as shown in Figure 2.

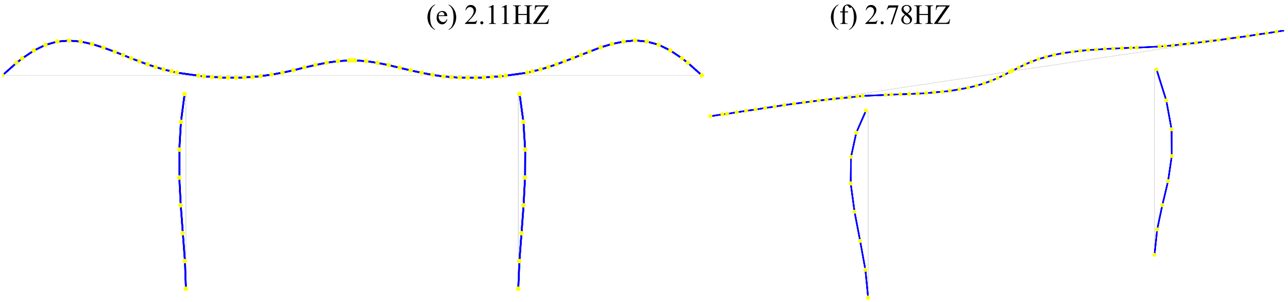


(a) 0.641HZ (b) 0.703HZ

(c) 1.12HZ (d) 1.55HZ



(e) 2.11HZ (f) 2.78HZ



(g) 3.10HZ (h) 3.54HZ

Figure 2 The modal shape for Jiujiapeng Bridge

It can be clearly seen from Figure 2 that the lateral bending modal shape and the vertical bending modal shape dominate the Bridge bending shape.

3 SEISMIC ANALYSIS USING THE GREAT MASS METHOD

3.1 The great mass method

The great mass is attached to the bridge pile foundations with mass of 10^{20} extent. The freedom along the excitation direction is released. The force is applied on the great mass with the amplitude of the multiplication of the great mass by the ground excitation. Thus the ground vibration variation can be considered easily.

Considering a dynamical equilibrium equation [3]:

$$[M]\{\ddot{u}\}+[C]\{\dot{u}\}+[K]\{u\}=\{P\} \qquad (1)$$

Considering a great mass with force $P_j = M_0 \ddot{U}_0$ (2)

Substitute Equation (2) into Equation (1)

$$\begin{bmatrix} m_{11} & \cdots & m_{1j} & \cdots & m_{1n} \\ \vdots & \vdots & \vdots & \vdots & \vdots \\ m_{j1} & \cdots & M_0 & \cdots & m_{jn} \\ \vdots & \vdots & \vdots & \vdots & \vdots \\ m_{n1} & \cdots & m_{nj} & \cdots & m_{nn} \end{bmatrix} \begin{Bmatrix} \ddot{u}_1 \\ \vdots \\ \ddot{u}_j \\ \vdots \\ \ddot{u}_n \end{Bmatrix} + \begin{bmatrix} c_{11} & \cdots & c_{1j} & \cdots & c_{1n} \\ \vdots & \vdots & \vdots & \vdots & \vdots \\ c_{j1} & \cdots & c_{jj} & \cdots & c_{jn} \\ \vdots & \vdots & \vdots & \vdots & \vdots \\ c_{n1} & \cdots & c_{nj} & \cdots & c_{nn} \end{bmatrix} \begin{Bmatrix} \dot{u}_1 \\ \vdots \\ \dot{u}_j \\ \vdots \\ \dot{u}_n \end{Bmatrix} + \begin{bmatrix} k_{11} & \cdots & k_{1j} & \cdots & k_{1n} \\ \vdots & \vdots & \vdots & \vdots & \vdots \\ k_{j1} & \cdots & k_{jj} & \cdots & k_{jn} \\ \vdots & \vdots & \vdots & \vdots & \vdots \\ k_{n1} & \cdots & k_{nj} & \cdots & k_{nn} \end{bmatrix} \begin{Bmatrix} u_1 \\ \vdots \\ u_j \\ \vdots \\ u_n \end{Bmatrix} = \begin{Bmatrix} P_1 \\ \vdots \\ M_0 \ddot{U}_0 \\ \vdots \\ P_n \end{Bmatrix} \quad (3)$$

The jth equation of Equation(3) can be obtained as follows:

$$m_{j1}\ddot{u}_1+\cdots+M_0\ddot{u}_j+\cdots+m_{jn}\ddot{u}_n+c_{j1}\dot{u}_1+\cdots+c_{jj}\dot{u}_j+\cdots+c_{jn}\dot{u}_n+k_{j1}u_1+\cdots+k_{jj}u_j+\cdots+k_{jn}u_n=M_0\ddot{U}_0 \qquad (4)$$

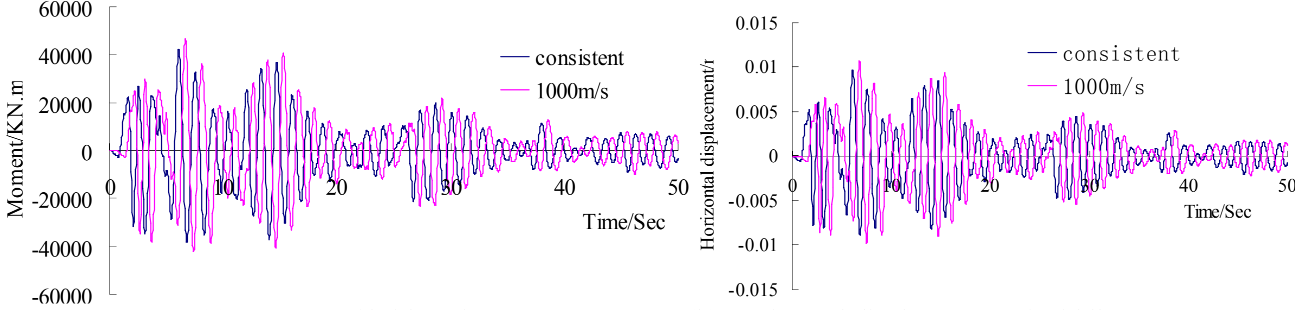
As M_0 exceeds other coefficients to a large extent, the value of $\ddot{u}_j$ can be obtained as $\ddot{U}_0$.

3.2 Seismic input considering traveling wave

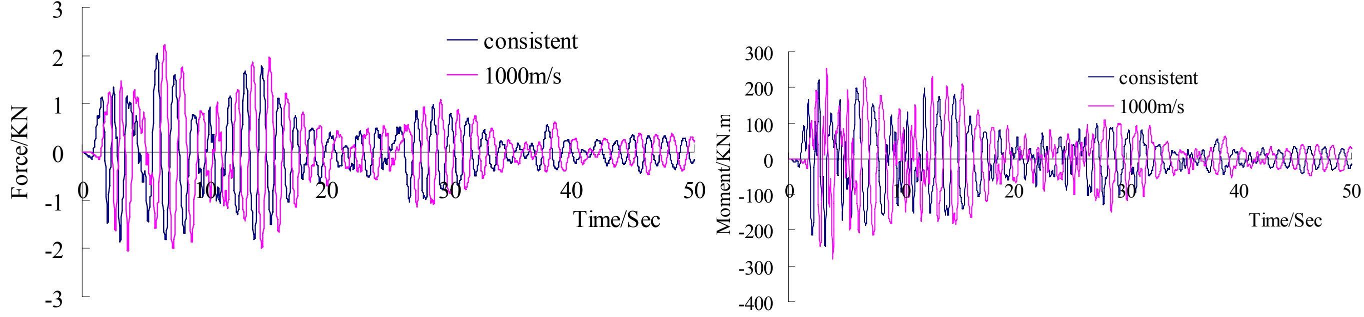
The traveling wave effect is caused by distances difference between different monitoring locations and the earthquake source center. The support points are relatively fixed for most engineering structures. Then the time lag between different support points when the seismic wave arrives is determined by the pseudo wave velocity and the angle θ between the seismic wave propagation direction and the structure longitudinal axis. In the analyses, the θ is assumed as 0. The pseudo wave velocity is taken as 1000m/s. The EL-Centro seismic wave is taken and is modulated with the swing value of 0.05g.

3.2 Time-history analysis

With the application of the great mass mthod, the time-history analysis is used to perform the seismic analysis using the finite element dynamical incremental analysis. The time increment is taken as 0.02s which is the same as the sampling interval of EL-Centro seismic wave. The total analysis time is taken as 50s. For comparison, the time-history analyses for both the consistent seismic wave input and the seismic input considering traveling wave effect are performed in the paper. Some typical structural member time-history results are shown in Fig. 3



(a) Moment of bridge pier (b) Horizontal displacement of middle span



(c) Axial force of middle span (d) Moment of middle span

Figure 3 Time-history result for bridge pier and middle span box girder

It can be clearly seen from Figure 3 that the traveling wave does not influence the maximum value of bridge pier moment and middle span box girder internal force greatly. The traveling wave effect on the bridge response is reflected in the extreme value occurrence time.

4 CONCLUSION

The great mass method is proposed in the paper to perform the multi-support bridge seismic analysis with consideration of traveling wave effect. As a case for study, the Jiujiapeng Bridge seismic analysis is performed under traveling wave for the frequent seismic analysis. The analysis result shows that the traveling wave effect almost has the same result as the consistent seismic analysis. The maximum response value of bridge box girder in the middle span and the bridge pier moment obtained from the great mass method is a little larger than that obtained from the consistent seismic input analysis. The extreme value occurrence time in the great mass method is a little later than that in the consistent seismic input analysis.

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