SEISMIC ANALYSIS OF T SHAPE RIGID BRIDGE WITH HIGH PIERS

Qingxiang Zheng[1] and Wenhua Liu[2]
[1]Qufu Normal University, Qufu, China
[2]Chelbi Engineering Consultants Inc., Beijing, China
E-Mail: z.q.x.818@163.com

ABSTRACT

Combined with seismic resistance of T shape rigid bridge with high piers in Dina 2 gas-field of China, comparative analysis on double thin-wall piers and hollow thin wall pillar is carried out. Focusing on seismic performance of their dynamic properties and structure under the condition of one-way incentive and three-dimensional space incentive, we conclude that the seismic performance of double thin-wall piers is superior to hollow thin wall pillar, on the basis of the fact that double thin-wall piers contains more than hollow thin wall pillar low-frequency vibration frequency in sectional characteristic and pier under the condition of high basic agreement, which is easily causing to frequency dispersion.

Keywords: T shape rigid bridge, seismic, thin-wall piers, vibration frequency, time-history analysis.

INTRODUCTION

In recent years, based on the steady construction development in the eastern, China's highway has extended gradually to mountainous area in western [1]. Mountainous highway is quite different to that of plain, and requires to a lot of high piers and bridge tunnel for its terrain restriction [2]. We make use of economic and reasonable piers to build high bridge pier, which is especially important to the bridge durability for high seismic grade area. Among those pier forms, we trends to apply the widespread double thin-wall piers and hollow thin wall pillar to construction [3]. The Dina 2 gas field ground construction project lies in south Tianshan mountain of Xinjiang province, China, including 2 main well area road, feeder roads, well site and typical drill. Because the mountain in this area is steep and is weathered seriously, further together with the geography characteristics, Main road K8 + 605 adopts 2-82m T shaped steel structure bridge scheme , box girder beams body ,with double thin-wall piers, and the high of body pier is 74.5 m, using C50 concrete. According to China's seismic code zoning [4], its designing structure is within in 8 degree seismic fortification intensity area. And the geological prospecting shows that its kind of site for class is II venues; peak acceleration ground motion is 0.2 g, and seismic response feature period is 0.35 s. As seismic response analysis is a necessary link in its design [5], we completed time-history analysis on a high pier T-shaped Bridge under the action of ground motion, and based on the analysis, suggestion about high piers design original section was put forward to.

SECTION DESIGN AND CHARACTERISTICS

Under earthquake excitation, the seismic response of pier's structure of the Dina 2 gas field high piers T shape bridge, along the bridge pier or horizontal bridge, will follow to the X axis or the Y axis (Figure-1). Hollow thin wall pillar is used in building T-shape steel structure bridge to its initial design, because the integrity of hollow thin wall pillar is better, and has a greater resistance to twist inertia than double thin-wall piers [6]. Therefore whether resistance to the magnitude of the earthquake or not is not only decided by the pier cross-section bending moment of inertia IX and IY, but also to a greater extent by structure itself and its vibration characteristics [7]. Eventually scheme with double thin wall pillar is utilized in constructing T-shape steel Structure Bridge, and section size as shown in Figure-2A. Owing to the complexity of earthquake ground motion, this article will compare dynamic properties and seismic dynamic response of two piers and the result will be used to guild the design. It is difficult for ground motions to guarantee its positive incentive straightly along the X, Y or Z direction, yet there is an angle between them [8]. Then this article contrasts three reactions of structure under the incentive from X, Y or Z direction respectively with the reaction of three incentives simultaneously. Double thin-wall piers' and hollow thin wall pillar's sectional dimensions of T-shape steel structure bridge are shown in Figure-2 and their section parameter comparison in table 1. Two section area differ about 1.2%, IY of inertia differ about 8%, Double thin-wall piers IX and IZ were less than hollow thin wall pillar about 31.8% and 735.3% separately.

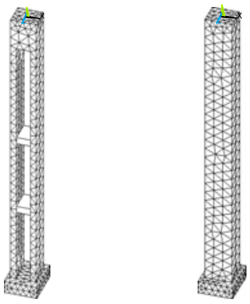
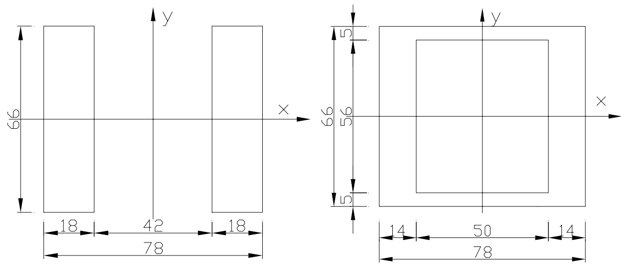

(A) (B)

Figure-1.

A. The model of double thin-wall piers.
B. The model of hollow thin wall pillar.



(A) (B)

Figure-2.

A. Double thin-wall piers section size.
B. Hollow thin wall pillar section size.

Table-1. Double thin-wall piers and hollow thin wall pillar section parameter.

Project	**A** (m^2)	**I$_x$** (m^4)	**I$_y$** (m^4)	**I$_z$** (m^4)
Double thin-wall piers	23.76	86.249	220.255	21.27
Hollow thin wall pillar	23.48	113.700	202.670	177.666
Difference (%)	-1.178	31.828	-7.984	735.289

DYNAMIC ANALYSIS

In order to understand the dynamic characteristics of the pier, we give the first 10 order vibration frequency in Table-2. The top 50 order frequency distribution is shown in Figure-3, it is clear that vibration model of two piers is similar in the first five order, the first vibration model of double thin-wall piers swings along the X axis and hollow thin wall pillar along the Y axis. In the process, frequency of hollow thin wall pillar is growing faster, and article 10 order frequency of hollow thin wall pillar (21.274Hz) twice about of double thin-wall piers (9.667Hz). Double thin-wall piers have the low frequency mode more than hollowed thin wall pillar (Figure-3). The top 50 highest frequency of double thin-wall piers and hollow thin wall pillar are about 80Hz and 130Hz respectively. Figure-4 is the first and second order structure vibration type figure.

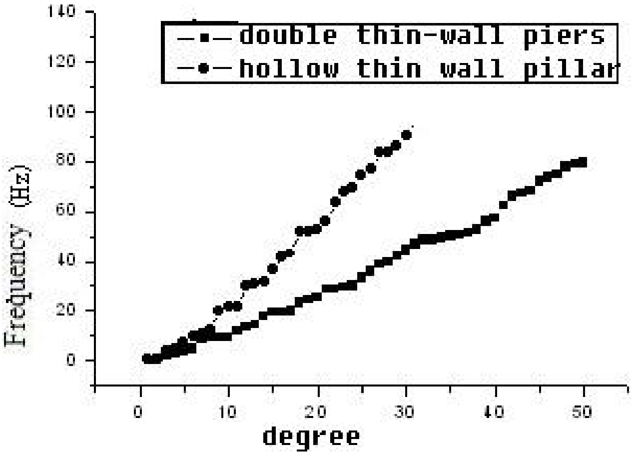


Figure-3. 1-50 order frequency distribution.

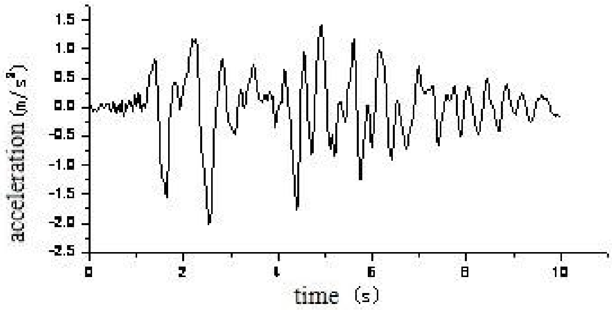


Figure-4. EI-centro acceleration schedule.

Table-2. The first 10 order vibration frequency.

Modal	Double thin-wall piers		Hollowed thin wall pillar	
	Frequency (Hz)	**Mode of vibration**	**Frequency** (Hz)	**Mode of vibration**
1	0.403	Swinging along the X axis	0.592	Swinging along the Y axis
2	0.530	Swinging along the Y axis	0.740	Swinging along the X axis
3	2.213	1/2 sine vibration in XZ plane	3.91	1/2 sine vibration in YZ plane
4	3.422	1/2 sine vibration in YZ plane	4.63	1/2 sine vibration in XZ plane
5	4.135	Turning around the Z axis overall	7.151	Turning around the Z axis overall
6	5.368	1 sine vibration in XZ plane	9.796	Up and down along the Z axis
7	9.562	1 sine vibration in YZ plane	10.747	1 sine vibration in YZ plane
8	9.667	Two piers opposite vibration up and down along the Z axis	12.03	1 sine vibration in XZ plane
9	9.681	3/2 sine vibration in XZ plane	20.069	3/2 sine vibration in YZ plane
10	10.324	Two piers opposite vibration	21.274	3/2 sine vibration in XZ plane

SEISMIC PERFORMANCE ANALYSIS

The long axis and short axis of section are marked as X, Y axis, respectively and the direction for pier height as Z axis. A single seismic excitation from the X, Y and Z direction, respectively and concentrated seismic excitation from the three directions simultaneously are exerted to pier, and earthquake acceleration schedule is from EI - Centro wave (Figure-4), Maximum acceleration 0.2 g. Then comparative analysis for reaction to incentive to two piers is conducted. We use Newmark- β Theory, $\alpha = 0.5$, $\beta = 0.25$ to compute the solution, Damping ratio of structure each vibration mode is referred to as 0.02, in view of length restrictions, here are only part of the computational results, namely the position shown in Figure-5 where the pier node response locate.

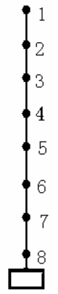
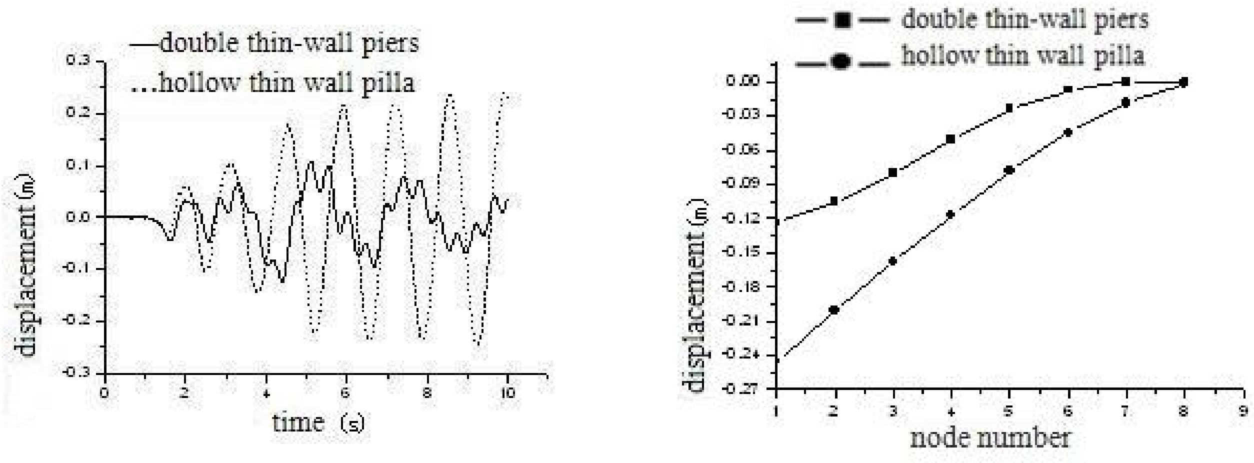


Figure-5. The nodes of Pier.

The maximum seismic excitation response along X direction

Displacement time-history under the condition of X direction seismic excitation on the top of the two piers is shown in Figure-6. In 4.4s double thin-wall piers have the maximum displacement response on the top about 0.124m and in 9.24s hollow thin wall pillar has the maximum displacement response about 0.124m. Figure-6B displays the displacement response of two piers from one to eight nodes in the 9.24s and 4.4s. Maximum displacement response shape of two piers coincides well with the first mode shapes in the direction.



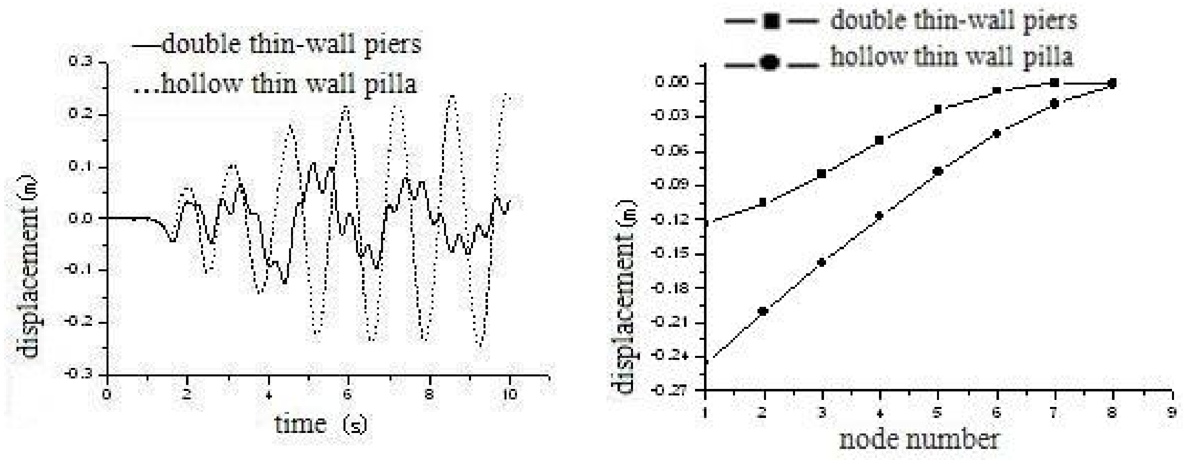
(A) (B)

Figure-6.

A. Displacement response schedule of Pier top.
B. The maximal displacement response of pier column.

The maximum seismic excitation response along Y direction

Displacement time-history under the condition of Y direction seismic excitation on the top of the two piers is shown in Figure-7. In 9.64s double thin-wall piers have the maximum displacement response on the top about 0.183 m, and in 7.38s hollow thin wall pillar has the maximum displacement response about 0.176 m. Figure-7B displays the displacement response of two piers from one to eight nodes in the 9.64 s and 7.38 s. Maximum displacement response shape of two piers coincide well with the first mode shapes in the direction.



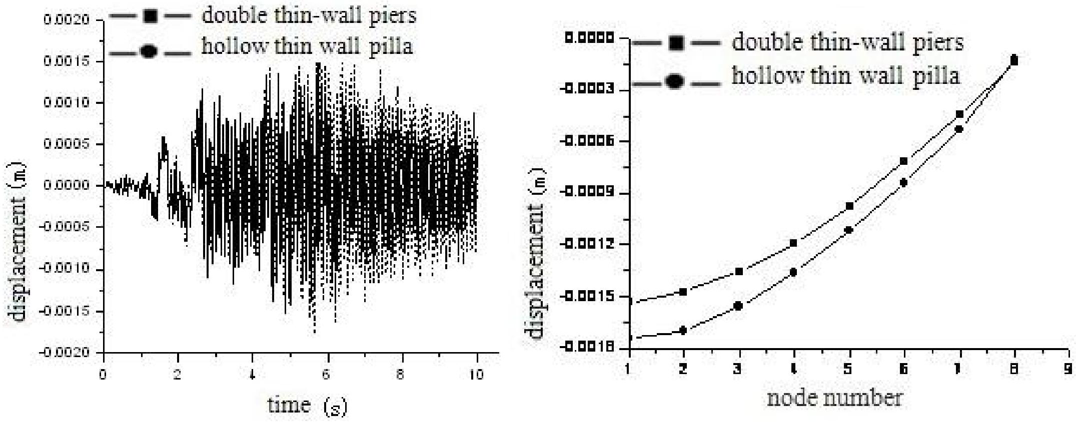
(A) (B)

Figure-7.

A. Displacement response schedule of Pier top.
B. The maximal displacement response of pier column.

The maximum seismic excitation response along Z direction

Displacement time-history under the condition of Z direction seismic excitation on the top of the two piers is shown in Figure-8. In 4.86s double thin-wall piers have the maximum displacement response on the top about 0.00154m, and in 5.64s hollow thin wall pillar has the maximum displacement response about 0.00175m. Figure-8B displays the displacement response of two piers from one to eight nodes in the 9.64s and 7.38s. Maximum displacement response shape of two piers coincides well with the first mode shapes in the direction.



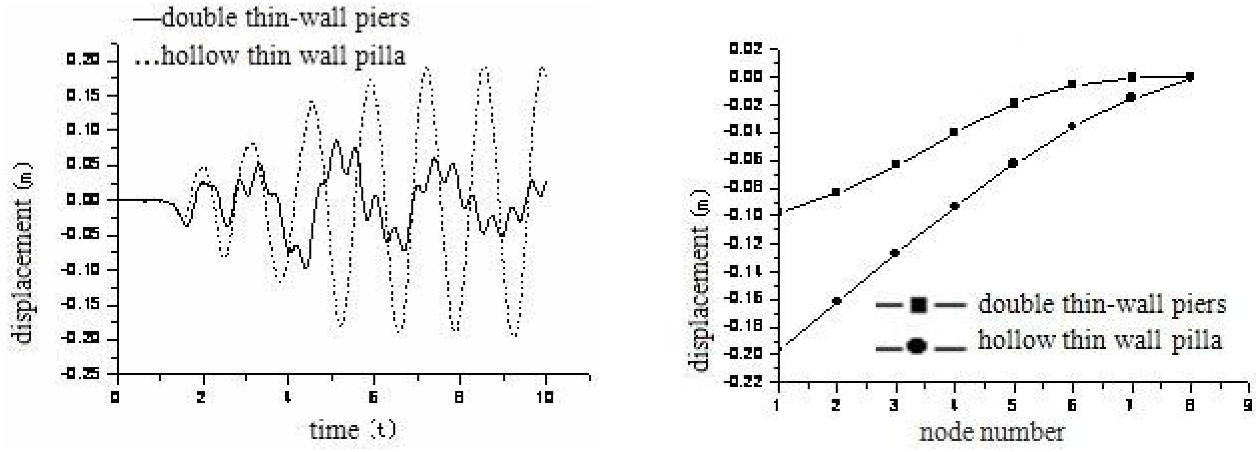
(A) (B)

Figure-8.

A. Displacement response schedule of Pier top.
B. The maximal displacement response of pier column.

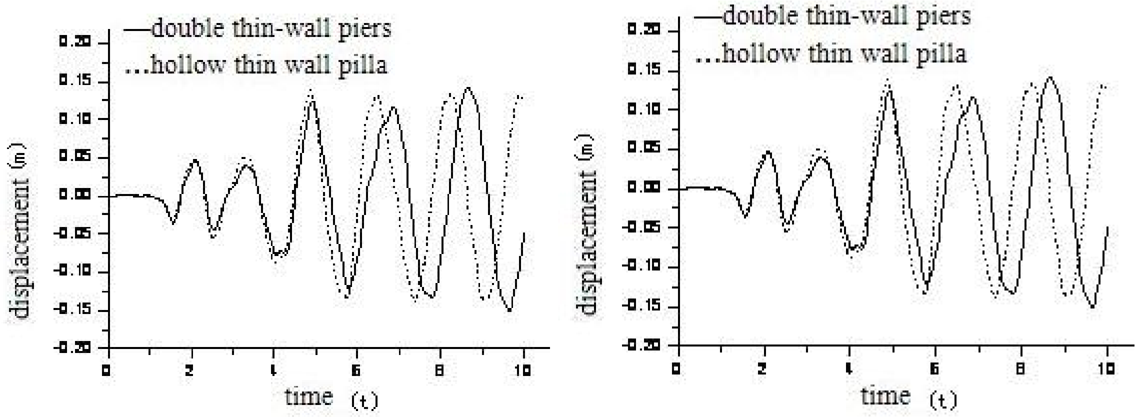
The maximum response due to space seismic excitation

Structural reaction to earthquake excitation under the circumstances of three-dimensional space in three directions demonstrates in Figures 9, 10 and 11, from which we can draw a conclusion that in terms of time-history and maximum displacement response of column top in three directions, hollow thin wall pillar are larger than double thin-wall piers, among them, along X direction and Z direction the maximum displacement response of hollow thin wall pillar is twice about thin-wall piers, and in the Y direction the displacement response of both have slight difference.



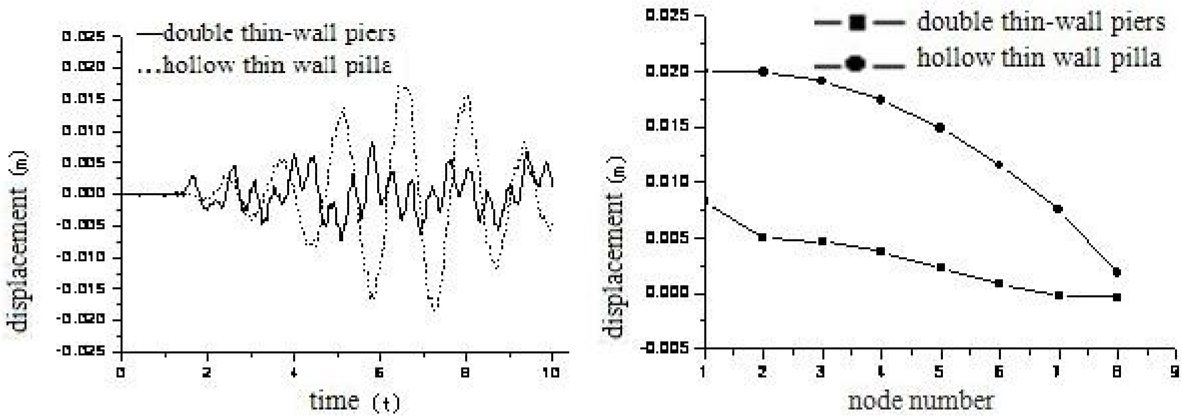
(A) (B)

Figure-9.
A. Pier top displacement response schedule along X direction
B. Pier column the maximal displacement response along X direction



(A) (B)

Figure-10.
A. Pier top displacement response schedule along Y direction
B. Pier column the maximal displacement response along Y direction



(A) (B)

Figure-11.
A. Pier top displacement response schedule along Z direction
B. Pier column the maximal displacement response along Z direction

CONCLUSIONS AND RECOMMENDATIONS

From the above analysis, it can be seen that when double thin-wall piers and hollow thin wall pillar section area are basically the same (differ about 1.2%), inertia IY is similar(about 8%), double thin-wall piers IX and IZ are less than hollow thin wall pillar (differ about 31.8% and 735.3%). By analyzing the high piers formed, among the top 50 order vibration frequency of the highest, frequency of double thin-wall piers is around 80HZ and yet the highest frequency of hollow thin wall pillar is about 130HZ. As a result, the low frequency of double thin-wall piers is distributed more widely than that of hollow thin wall pillar. Seismic performance analysis can be concluded as follows:

Inspired by the X direction, the maximum displacement response of hollow thin wall pillar is about twice of double thin-wall piers. Inspired by the Y direction, the maximum displacement response of hollow thin wall pillar and double thin-wall piers is similar. Inspired by the Z direction, the maximum displacement response of hollow thin wall pillar is about 20% more than that of double thin-wall piers.

In the earthquake excitation in 3d space, the maximum displacement response of hollow thin wall pillar from the X direction and Z direction is about twice of double thin-wall piers. The displacement response of the both from the Y direction differs not quite.

Seismic performance of 74.5 m high double thin-wall piers is better than the hollow thin wall pillar .Finally, it is reasonable to adopt double thin-wall piers scheme.

REFERENCES

[1] Wang K.H. and Sun Y.H. 2008. Comments on Seismic Strengthening for Structural Engineering in China after Wenchuan Earthquake (in Chinese). Journal of Highway and Transportation Research and Development. 25(11): 54-59.

[2] Song X.D. and Li J.Z. 2004. Seismic Conceptual Design for Mountain Bridges (in Chinese), Earthquake Engineering and Engineering Vibration. 24(1): 92-96.

[3] Li R., Ning X. and Ye L. 2001. Earthquake response analysis of Girder Bridge with high pier (in Chinese). Journal of Kunming University of Science and Technology (Science and Technology). 26(10): 86-89.

[4] Ministry of Transport, China, (JTG/T B02-01-2008). 2008. Guidelines for Seismic Design of Highway Bridges (in Chinese).

[5] Hu S. and Fan L.C. 1994. Jiangyin changjiang river highway bridge vertical seismic response analysis (in Chinese). Tongji University News. 22(4): 434-438.

[6] Tian Y.J. and Yang Q.S. 2006. Model analysis of structural response under the action of earthquake ground motion (in Chinese). Engineering Mechanics. 22(6): 170-174.

[7] Wilson E.L. 2002. Three-dimensional static and dynamic analysis of structures. Computers and Structures [M]. 234-249.

[8] Ma K.Q. 1995. Big span high piers of continuous girder bridge space seismic response analysis (in Chinese). Journal of Shanghai Railway Institute. 16(2): 21-29.