Available online at www.sciencedirect.com

ScienceDirect

Procedia - Social and Behavioral Sciences 218 (2016) 104 – 117

Procedia
Social and Behavioral Sciences

11th International Conference of the International Institute for Infrastructure Resilience and Reconstruction (I3R2)
: Complex Disasters and Disaster Risk Management

Investigation of seismic response on girder bridges: the effect of displacement restriction and wing wall types

Desy Setyowulan[a,b*], Toshitaka Yamao [a*], Keizo Yamamoto[a*], Tomohisa Hamamoto[c*]

[a] *Graduate School of Science and Technology, Kumamoto University, 2-39-1 Kurokami, Kumamoto, 860-8555, Japan*
[b] *Civil Engineering Department, Universitas Brawijaya, No. 169 MT Haryono Street, Malang, East Java, Indonesia*
[c] *Civil Engineering Department, Gunma National College of Technology, 580, Tribamachi, Maebashi, Gunma 371-8530, Japan*

Abstract

In the seismic design specified by Japanese Specifications of Highway Bridges (JSHB), a large gap size between two adjacent girders or the girder and abutment has recommended to be constructed in the concrete girder bridge with multi-spans in order to prevent the collision, when it is subjected to Level 2 ground motion. However, the adoption of large gap into PC bridge will increase the construction and seismic reinforcement costs since relatively large expansion joints have to be used. Also, it causes the girders falling in the presumption of strong earthquake. It has been suggested that allowing the girder collision at the abutment by restricting the girder bridges displacement, the size of expansion joints can be reduced. These conditions are able to reduce the seismic design and seismic reinforcement cost.
Although many studies on the effect of the collision have been published, the effect of displacement restriction of girders is still remains to be elucidated. This present study aims to investigate the seismic response of concrete girder bridges taking into account the effect of displacement restriction of girders allowing the girder collision at the abutment and the wing wall. Two span concrete girder bridge was examined in theoretically by 3D FEM model of ABAQUS with four different approaches at the wing wall abutment model. The dead load and soil pressure were calculated based on JSHB loading conditions and gap between superstructure and parapet wall was chosen to be 10 cm and 20 cm. Level 2 earthquake ground accelerations were applied horizontally at the bottom of pier. The numerical results showed that the parameters such as shear stress, response stress, displacement, and cracking were affected by displacement restriction and different wing wall model. Installing of the wing wall in abutment generally increased the response stress in parapet wall and shear stress around vertical wall of abutment. In contrast, it significantly reduced the horizontal displacement of abutment.

Peer-review under responsibility of Dept of Transportation Engineering, University of Seoul.

Keywords: collision; displacement restriction; gap; impact force; seismic response; wing wall abutment

1. Introduction

A large number of bridges were damaged during unexpectedly severe earthquakes, such as 1995 Hyogo-ken Nanbu earthquake and 2011 Tohoku earthquake. Damage to bridges primarily occurred in reinforced concrete substructures, buckling of steel piers, collapsed span as a result of insufficient support length and bearing damage. During the inspection of the failure, the most common problems observed for collapsed of abutments were caused by high stress on the surface of abutment and collision between adjacent deck and between deck and abutment. Therefore, a new type of abutment is required in order to generate an appropriate abutment model with a better seismic performance. Seismic response investigation of reinforced concrete abutment is very important in term of the ability to survive in severe earthquake. Furthermore, a proper material model of reinforced concrete should be capable in representing the behavior of materials within finite element packages.

---

*Corresponding author. Tel.: +62-8123-364-6603
E-mail address: desy_wulan@ub.ac.id (D. Setyowulan), tyamao@kumamoto-u.ac.jp (T. Yamao), keizo.yamamoto1110@gmail.com (K. Yamamoto), hamamoto@cvl.gunma-ct.ac.jp (T. Hamamoto)

Peer-review under responsibility of Dept of Transportation Engineering, University of Seoul.
doi:10.1016/j.sbspro.2016.04.014

Nomenclature

C	damping matrix
M	mass matrix
K	stiffness matrix
α	coefficient for mass matrix (sec^{-1})
β	coefficient for stiffness matrix (sec)
P_{EA}	active earth pressurestrength (kN/m^2) during an earthquake at depth x (m)
K_{EA}	coefficient of active earth pressure during an earthquake
k_h	design horizontal seismic coefficient used for calculation of earth pressure during an earthquake
r	unit weight of soil (kN/m^3)
q'	surcharge on the ground surface during an earthquake (kN/m^2)
ϕ	angle of shear resistance of soil (degree)
α	angle formed between the ground surface and horizontal plane (degree)
θ	angle formed between back surface of a wall and a vertical plane (degree)
δ_E	wall surface friction angle between the back surface of a wall and soil (degree)
θ_o	$\tan^{-1} k_h$ (degree)

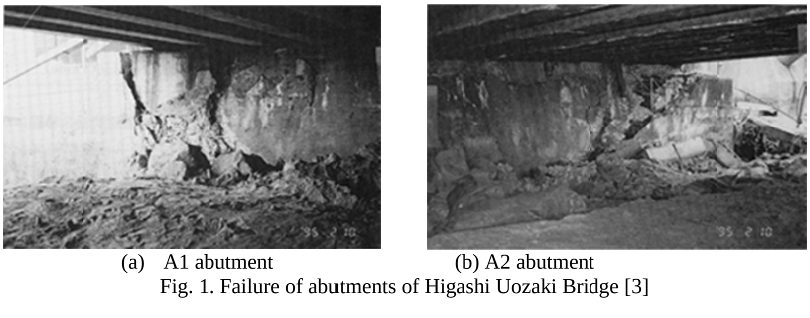
In the seismic design specified by Japanese Specifications of Highway Bridges (JSHB), a large gap size between two adjacent girders or the girder and abutment has recommended to be constructed in the concrete girder bridge with multi-spans in order to prevent the collision, when it is subjected to Level 2 ground motion. However, the adoption of large gap into PC bridge will increase the construction and seismic reinforcement costs since relatively large expansion joints have to be used. It has been suggested that allowing the girder collision at the abutment by restricting the girder bridges displacement, the size of expansion joints can be reduced. These conditions are able to reduce the seismic design and seismic reinforcement cost.

Previous researcher [1] investigated the effect of collision between parapet wall and superstructure due to the variation of gap from 10 cm to 50 cm.The effect of earth pressure during earthquake was not taken into account. According to this analysis, it was found that increasing of gap for bridge with and without installation of the wing wall decreased the number of collision. In general, applying the gap of 20 cm and 30 cm had a good effect on reducing the response stress of parapet wall. However, they were varied on different input seismic motions. In addition, installation of the wing wall in parapet had a capability in reducing the maximum response stress of parapet wall, which contributed greatly to the horizontal resistance of abutment against load.

In this study, the seismic response on concrete girder bridges taking into account the effect of displacement restriction and wing wall types was discussed. Four different abutments modeling approaches [2] were installed in two spans concrete girder bridges subjected to Level 2 seismic ground motions. Gap between superstructure and parapet wall was chosen to be 10 cm and 20 cm to analyze the effect of displacement restriction on the behavior of abutments. Effect of earth pressure during earthquake was taken into account.

2. Literature reviews

Collapsed of Higashi Uozaki Bridge which passed over the canal, an example of damaged in abutment due to strong intensity of dynamic excitation from 1995 Hyogo-ken Nanbu earthquake, are shown in Fig. 1 [3]. According tho this figure, it is described that A1 abutment rotated backward and accompanied with large cracks widespread on the front face of the abutment. The shear collapse with widely opening cracks on the front face was also observed at A2 abutment wall. This condition may occurred due to several reasons, such as the liquefaction of the subsoil layer, the earth pressure acting on the back face of the abutment which was pushed outward and the inertial force itself, the lateral movement at the top of abutment was constrained by the deck, and the large tensile force acting at the front face of the abutment.



(a) A1 abutment (b) A2 abutment

Fig. 1. Failure of abutments of Higashi Uozaki Bridge [3]