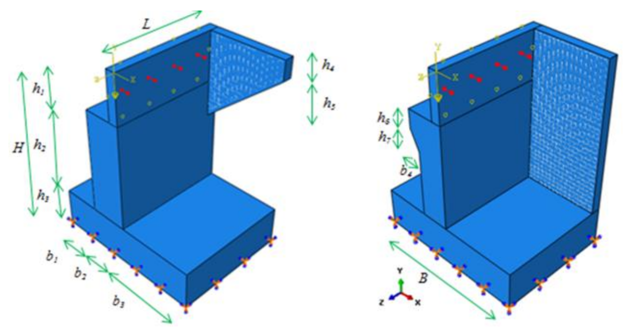
Dynamic Analysis of Reinforced Concrete Abutments Subjected to Ground Motion

Kumamoto University, GSST. Student Member. Desy Setyowulan
Gunma National College of Technology, Tomohisa Hamamoto
Kumamoto University, GSST. Fellow Member. Toshitaka Yamao

１. Introduction

Earthquake has been noticed as the most frightened phenomenon of nature. In earthquake-prone areas, a bridge is unavoidably attacked by an earthquake. Once bridge collapse during earthquakes, it will seriously affect the transportation network for the victims, rehabilitation work and economic activities. There are several damages of bridge during earthquake, especially in abutment. As an example is the abutment damage occurred in the Attica earthquake in Peru, June 2001. The north abutment of the Puente Los Banos Bridge experienced significant displacement and rotation[1]. Consequently, it is necessary to check the seismic performance of typical abutment model in Japan. Furthermore, it is important to develop an abutment model with high seismic capacity.



(a) Typical model (b) Proposed model

Figure 1. Theoretical reinforced concrete abutments

Table 1. The dimension of abutments

Descrip-tions	Typical Model	Proposed Model	Descrip-tions	Typical Model	Proposed Model
L	8.0	8.0	h_1	2.5	2.5
B	6.0	6.0	h_2	5.5	5.5
H	10.0	10.0	h_3	2.0	2.0
l_1	2.0	2.0	h_4	1.0	-
l_2	2.0	2.0	h_5	3.3	-
l_3	4.0	4.0	h_6	-	1.0
l_4	-	0.5	h_7	-	1.0
t	0.5	0.5			

2. Outline of Dynamic Analysis

The theoretical reinforced concrete abutment for the typical model is representative for actual half-length model of abutment in Japan. In order to develop an abutment with high seismic capacity, the proposed model of abutment was analyzed (Fig. 1).

The dimensions of abutments are shown in Table 1. The thickness of the parapet wall and the wing wall were assigned by t. Material properties of the models were assumed to be concrete with Young's modulus E_c of 25 GPa, Poisson's ratio υ_c of 0.2, compressive strength f'_c of 27.5 MPa and reinforcing bar with a yield stress f_y of 375.3 MPa, E_s of 200 GPa and υ_s of 0.3. The boundary condition was fixed at the footing of abutment and the dead load reaction from superstructure was 2900 kN.

The Hyogo-ken Nanbu earthquake 1995 as level 2 ground motion was used as input ground acceleration in longitudinal and out-of-plane direction with the record location in EW direction (Level 2 II-I-2) and NS direction (Level 2 II-I-1), respectively[2]. In this analysis, composite modal damping of 5% was used in order to reduce the vibration of structure during earthquake.

Table 2. Results of eigenvalue analysis

Order of Periods	Typical Abutment T (sec)	Typical Effective Mass Ratio X	Typical Effective Mass Ratio Y	Typical Effective Mass Ratio Z	Proposed Abutment T (sec)	Proposed Effective Mass Ratio X	Proposed Effective Mass Ratio Y	Proposed Effective Mass Ratio Z
1	0.0	8.64	0.30	4.52	0.06	2.26	0.00	12.9
2	0.0	**38.36**	0.66	1.44	0.04	**53.01**	0.00	3.68
3	0.0	7.73	1.06	1.94	0.03	2.16	0.00	17.6
4	0.0	0.22	0.23	**53.76**	0.02	0.03	0.01	5.52
5	0.0	16.77	0.60	2.79	0.02	11.04	0.06	**32.1**
6	0.0	0.05	1.37	3.24	0.02	4.55	0.03	2.04
7	0.0	0.08	0.02	0.07	0.01	0.55	0.01	0.21
8	0.0	0.05	0.00	0.87	0.01	0.00	0.36	0.64
9	0.0	0.01	2.62	6.42	0.01	1.26	0.14	1.04
10	0.0	1.70	**66.6**	1.84	0.01	9.02	20.39	0.07
11	0.0	2.38	9.80	18.71	0.01	0.39	2.32	11.3
12	0.0	23.75	12.6	0.67	0.01	2.18	**74.56**	0.04

3. Eigenvalue Analysis

The eigenvalue analysis was carried out in order to investigate the effect of the wing wall on the natural periods of

キーワード：Abutment, displacement, dynamic, eigenvalue, stress, strain
連絡先 〒860-8555 熊本市中央区黒髪 2-39-1 熊本大学大学院自然科学研究科 TEL:096-342-3533

the abutments. Table 2 presents the natural periods and the effective mass ratio of each predominant mode of abutments in order to understand the fundamental dynamic characteristics of the structure. The maximum effective mass ratios in X, Y and Z directions imply the order of the predominant natural period.

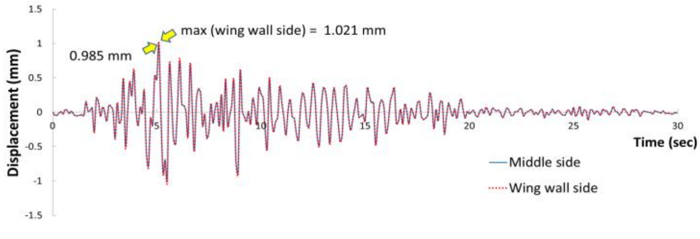
Table 3. Results of maximum displacements

Direction	Model	Longitudinal displacement (mm)		Out-of-plane displacement (mm)	
		Middle	Outer	Middle	Outer
EW (U1)	Typical	0.985	1.021	0.002	0.006
	Proposed	0.941	0.327	0.079	0.101
NS (U3)	Typical	0.054	0.159	0.233	0.196
	Proposed	0.116	0.182	0.267	0.221

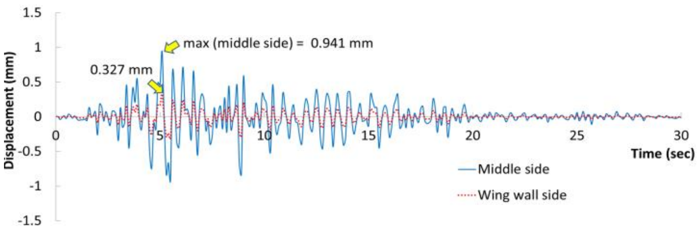
4. Response Behavior and Discussions

The dynamic analysis of the reinforced concrete abutment model was conducted in modal dynamic analysis by ABAQUS software[3]. The displacement was checked at the top of parapet wall (Table 3). It can be seen that the input seismic wave in longitudinal direction (X-direction) induces a larger displacement compare with seismic wave in out-of-plane direction (Z-direction). Furthermore, the wing wall impact not too significant in reducing the transverse displacement for all abutments.

Fig. 2(a) and 2(b) show the displacement response for typical and proposed abutment model in X-direction with an input seismic acceleration in EW direction, respectively. The longitudinal displacement for typical abutment model at the wing wall side is slightly larger than at the middle side. It is possibly due to the effect of the wing wall gravity to lead the displacement of the wing wall. Otherwise, the existence of the full wing wall for proposed model of abutment significantly reduce the longitudinal displacement at the wing wall side to be 0.327 mm compare with typical abutment model of 1.021 mm.



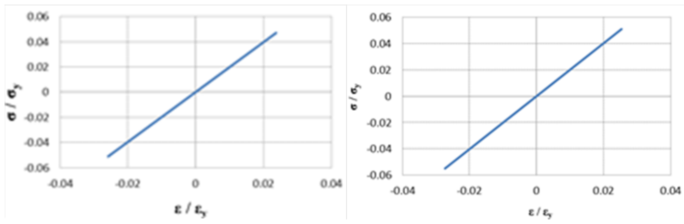
(a) Typical model



(b) Proposed model

Figure 2. Displacement-time history response in the top of parapet wall in X-direction (Level 2 II-1-2)

In order to understand the behavior of the abutment in out-of-plane directions, the hysteresis curves in the position of maximum values of stress and strain was observed (Fig. 3). The results indicate that both stress-strain ratios developed in the abutments are very small. Since the maximum stress do not reach their yield stress, it can be judged that this abutment model subjected to level II ground motion is not damaged.



(a) Typical model (b) Proposed model

Figure 3. Stress-strain relationship of abutments for input seismic wave in Z- direction (Level 2 II-1-1)

5. Conclusions

The typical model and proposed model of reinforced concrete abutment subjected Hyogo-ken Nanbu earthquake 1995 in longitudinal and out-of-plane directions were investigated by dynamic response analysis. The conclusions are summarized as the following.

1) The effect of the full wing wall depended on the direction of input seismic wave. In longitudinal direction, the displacement behavior was significantly affected by the wing wall, vice versa.
2) The abutments were judged not to damage under this earthquake waves because since the maximum stress do not reach their yield stress.
3) Input seismic wave in X-direction induce a larger displacement compare with seismic wave in Z-direction.

References

1) Shamsabadi, A. Three-Dimensional Nonlinear Seismic Soil - Abutment - Foundation - Structure Interaction Analysis of Skewed Bridges. Dissertation. Faculty of the Graduate School, University of Southern California, 2007.
2) Japan Road Association., "Specifications for Highway Bridges", Part I - Steel Bridge and Part V - Seismic Design, Japan, 2002.
3) Abaqus 6.11, Abaqus/CAE User's Manual". Dassault Systèmes Simulia Corp., Providence, RI, USA, 2011.