EXPERIMENTAL STUDY ON AN EXISTING BRIDGE RETROFITTED BY GROUND ANCHOR

Waseda University Student Member ○Yufan Liang
Waseda University Fellow Osamu Kiyomiya
Waseda University Regular Member Tongxiang An

1. INTRODUCTION

To improve the seismic performance of the bridge, many retrofitted methods have been proposed. As an indirectly retrofitting way, the ground anchor retrofit method has been adopting to improve the seismic performance of the structures such as port facility, dam, slope and so on. According to the existing research, the ground anchor connecting to the superstructure of bridge can improve the seismic performance of the whole bridge system. The validity of ground anchor retrofit method has been verified by numerical analysis. The aim of this work is to further verify the reinforcement effect of this method by shaking table test.

2. EXPERIMENTAL PROGRAM

2.1 Experimental Model

The prototype bridge used in this study was a typical highway bridge as shown in Fig. 1. The bridge was demonstrated in "Materials for Seismic Design of Highway Bridges". It was a 5-span continuous steel plate girder bridge with a total length of 200 m. The pier pillars were constructed of reinforced concrete and the foundation was constructed of concrete piles built on Type II ground. One of the bridge piers and the portion of superstructure weigh supported by the pier were considered in this study. The scale of the model was 1:16. The weight of the superstructure was modelled by steel plates. The horizontal stiffness of bearing system was offered by 6 springs that stiffness was 91.38 N/mm (6 x 15.23N/mm). The pillar of the pier was modelled by steel plates. The horizontal stiffness of foundation was obtained from cantilever steel rods and the rotational stiffness was offered by 20 springs arranged at both ends of the pile cap in shaking direction that stiffness was 3232.8 N/mm (20 x 161.64 N/mm) as shown in Fig. 2. Teflon was inserted between the superstructure plate and the top of the pier to reduce the friction resistance. 4 anchors were introduced to the retrofit case. The stiffness of anchor was 22.56 N/mm (4 x 5.64N/mm) offered by 4 springs, the effective retrofit ratio is 13% (22.56 x 0.521/91.38).

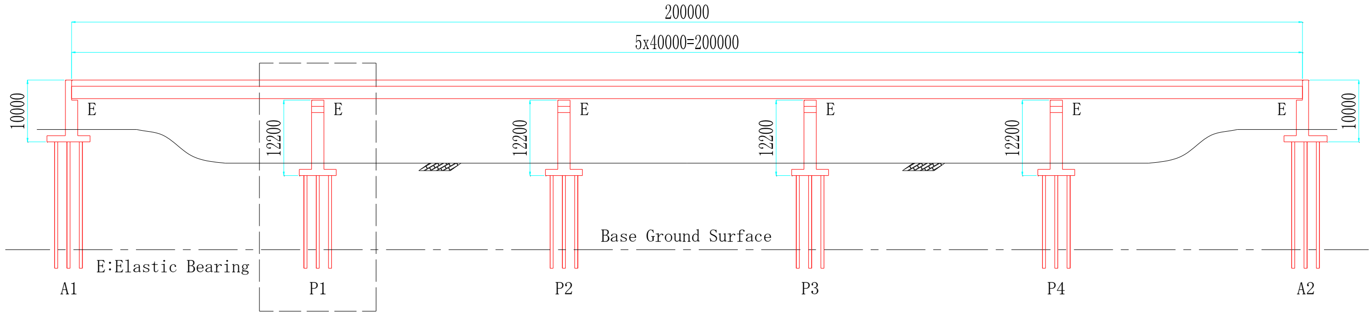

Fig.1 Prototype bridge & concerned pier (P1)

2.2 Instruments and Arrangement

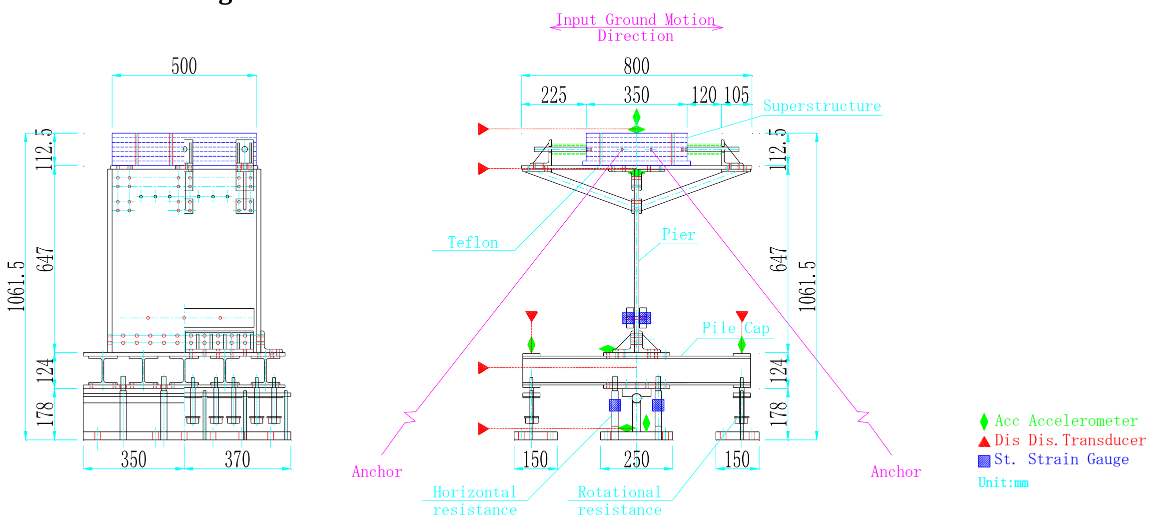

Fig.2 Experimental model (front view & side view)

Keywords: Existing bridge, Ground anchor retrofit, Reinforcement effect, Shaking table test
Contact address: Bldg. 51-16-01, 3-4-1 Okubo, Shinjuku-ku, Tokyo, 169-8555, Japan, Tel: +81-3-5286-3852

To investigate the vibration behavior and seismic performance of the structure, response accelerations, displacements and strains were recorded in the experiment. Accelerometers were arranged at the superstructure plate and the foundation in horizontal and vertical directions, as well as horizontally at the top of pier and pile cap, and vertically on both edges of the pier cap. The laser displacement meters were set up horizontally at the top of the superstructure plate, pier and pile cap, and the foundation, and vertically at the top of the pile cap. The strain gauges were installed at the bottom of the pillar and foundation. The detail of the experimental model and the instruments arrangement are shown in Fig. 2.

2.3 Input Ground Motion

Two types of waves were used as the input ground motions in this study. One was Sine waves used to investigate the vibration properties. Another was an earthquake wave considered for Level 2 seismic design (Type II ground motion), used to verify the seismic performance of the structure. It was modified from one of the Southern Hyogo Prefecture Earthquake (1995, inland direct strike type earthquake) records obtained on Type II ground, named Osaka Gas wave. The PGA was 736 Gal and the lasting time was 40 s. The model was shaken by shaking table test in horizontal direction. The amplitude of the input ground motion was increased step by step from 50%, 60%, 70%, 75% and 80%.

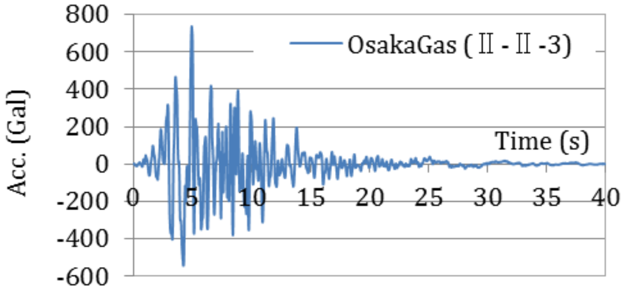

Fig. 3 Input ground motion (OsakaGas wave)

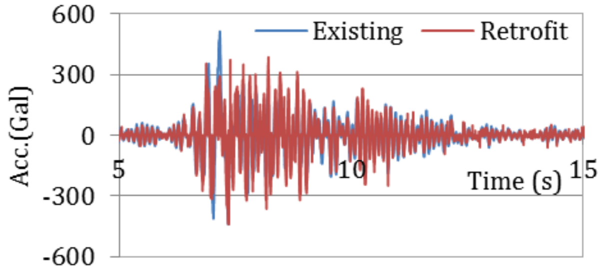

Fig. 4 Response acceleration of superstructure

3. RESULTS AND OBSERVATION

Fig. 4 shows the response acceleration of the superstructure. The maximum horizontal acceleration of existing bridge and retrofitted bridge were 513.88 Gal and 439.35 Gal, respectively. Fig. 5 illustrates the response displacements of the superstructure and Fig. 6 is the deformation of the bearing system. As to the existing bridge, the maximum horizontal displacements of superstructure and bearing were 28.6 mm and 30.6 mm, after reinforcement, the displacements were 26.3 mm and 27.6 mm, respectively. Table 1 shows the comparison of before and after reinforcement by ground anchor. The force of ground anchor was between 171.60 N and 297.40 N.

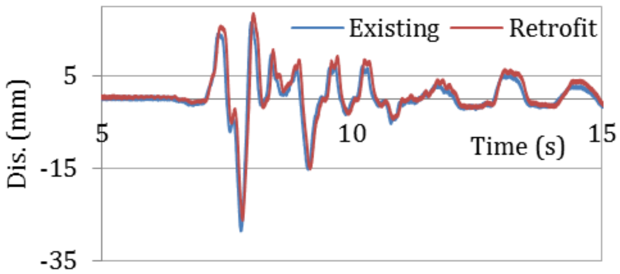

Fig. 5 Response displacement of superstructure

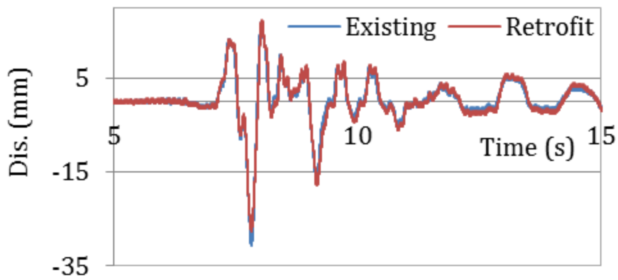

Fig. 6 Response deformation of bearing system

Table 1 Effects of reinforcement by ground anchor

Case	Acc. of Superstructure	Dis. of Superstructure	Deformation of Bearing	Horizontal reaction force of Foundation
	a (Gal)	d (mm)	d (mm)	H (kN)
Existing	513.88	28.6	30.6	0.103516
Retrofit	439.35	26.3	27.6	0.097058
R/E	85%	92%	90%	94%

4. CONCLUSION

The ground anchor retrofit method was verified by shaking table tests. The main findings are as follows: The response acceleration and displacement of the superstructure were reduced by the introduction of ground anchor. The deformation of the bearing was also reduced after reinforcement. The horizontal reaction force of foundation was reduced by 6% as well. These high performances by test result are almost the same as that by previous simulation result. The ground anchor retrofit method has effective action to improve the seismic performance of bridge associating with the reinforcement amount in this test. To obtain more reinforcement effect, the number of ground anchors, stiffness and strength of tendons, direction and angle of the ground anchor axis, and dampers should be considered in future work.

REFERENCES

[1] Japan Road Association: Materials for Seismic Design of Highway Bridges, 1997.
[2] Japan Road Association: Specifications for Highway Bridges, Part V Seismic Design, 2012.