Vibration Behaviour and Seismic Performance of an Existing Bridge Retrofitted by Ground Anchor

Tongxiang AN
Associate Professor
Waseda University
Tokyo, Japan
antongxiang@aoni.waseda.jp

Tongxiang An, born 1965, received his civil engineering degree from Lanzhow Jiaotong University, China

Osamu KIYOMIYA
Professor
Waseda University
Tokyo, Japan
K9036@waseda.jp

Osamu Kiyomiya, born 1948, received her civil engineering degree from Tokyo Institute of Technology, Japan

Summary

The vibration behaviour and seismic performance of an existing girder bridge with laminated rubber bearings is being discussed. The bridge was retrofitted by ground anchors and was verified by nonlinear dynamic analysis. As a result, ground anchors had a significant effect on improving the vibration behaviour and seismic performance of the whole bridge.

Keywords: vibration behaviour and seismic performance; existing bridge; seismic retrofit; ground anchor; nonlinear dynamic analysis; 2011 off the Pacific Coast of Tohoku Earthquake.

1. Introduction

The seismic retrofit of the existing bridges by the jacketing method used to improve the proof strength of the pier column generally adds a further load to the bridge foundation structures, while improving the earthquake resistance of the pier columns. When a bridge is reinforced by ground anchors, it is thought that the improvement of the seismic performance of the whole structure might be expected and the influence on the bridge foundation structure from the seismic reinforcement is little because the ground anchor is directly anchored to the ground and part of the inertia force is transferred to the ground.

2. Prototype bridge, outline of reinforcement and analytical model

A typical highway bridge was considered in this work. The bridge was a 5-span continuous steel plate girder with a total length of 200 m and weight of 31400 kN. The superstructure was composed of 5 girders and supported elastically both in longitudinal and transversal directions on all sub-structures except in transversal direction on both of the abutments. The girder was fixed at the ends in transversal direction. The substructures were built of reinforced concrete. The bearings were built of laminated rubber with the shear modulus of 0.8 MPa. The effective thickness of the bearings for abutments was 168 mm (24 mm@7 layers) and that for piers was 96 mm (24 mm@4 layers). The characteristic value of the surface ground (T_G) was 0.304 s (Type II ground for seismic design).

As an example, the reinforcement in longitudinal direction was introduced. A total of 20 (10 for each side) F310TA ground anchors were assumed to be connected to the two ends of the superstructure by 20 steel cables of 19 φ12.4 in this reinforcement work. The angle between the anchors and the horizontal direction was assumed to be 30 degrees as shown in Fig. 1.

The prototype bridge was modelled to a 3-D frame and the nonlinear dynamic response analysis method was adopted in this work.

3. Input ground motions and analytical method

Acceleration time history was used as the input ground motion in this work. Four earthquake waves were considered. One of them was recommended by "Seismic design specifications for highway bridges" for Level 2 seismic design (Type 2 ground motion). The other three waves were recorded

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from the 2011 Off the Pacific Coast of Tohoku Earthquake (hereinafter referred to as 2011 Tohoku

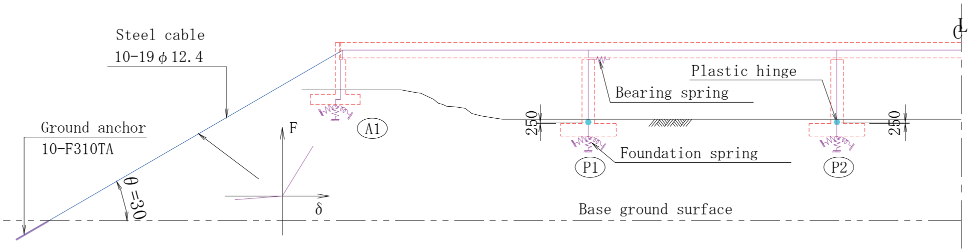

Fig. 1: The outline of reinforcement and analytical model

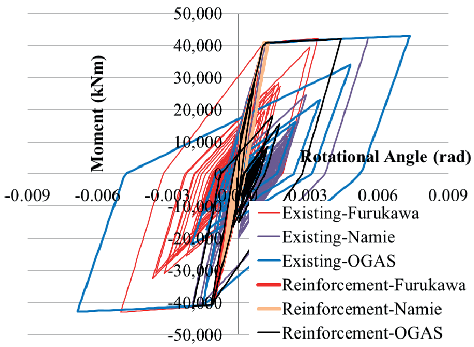

Fig. 2: The response of the plastic hinge

Table 1: The deformation of rubber bearing

Ground Motion	Abutment Existing		Abutment Reinforcement	Pier Existing		Pier Reinforcement
Sendai	181%	(238)	142%	232%	(188)	196%
Namie	231%	(230)	137%	286%	(177)	184%
Furukawa	226%	(189)	113%	275%	(139)	145%
OGAS	285%	(343)	204%	363%	(238)	248%

( ) denote displacement: mm

Earthquake) on Type II ground. One was the NS component of MYG013 that was named Sendai wave. One was the EW component of FKSH20 that was named Namie wave. The other was the EW component of MYG006 that was named Furukawa wave.

Table 2: The reaction forces of the foundations

		Namie		Furukawa		OSGAS	
		H (kN)	M (kNm)	H (kN)	M (kNm)	H (kN)	M (kNm)
A1	Existing	7445	27526	5761	27251	7782	34938
	Retrofit	7015	22142	4882	18134	8220	28842
	R/E	0.942	0.804	0.847	0.665	1.056	0.826
P1	Existing	8725	83496	8366	83867	10099	101320
	Retrofit	7659	58993	5903	53256	9883	84327
	R/E	0.878	0.707	0.706	0.635	0.979	0.832

H: horizontal reaction force; M: rotational reaction force

4. Reinforcement effect

The deformation of the rubber is shown in Table 1. After reinforcement, the maximum shearing strains were calculated by OGAS, which were 204% and 248% for A1 and P1, respectively. The introduction of the ground anchor greatly reduced the shearing strain of the rubber bearings. The hysteretic loop of the rotational moment against the angle of P1 plastic hinge is shown in Fig. 2. The reinforcement had a large effect on improving the seismic performance of the bridge pier. Table 2 shows the reaction forces of A1 and P1. The introduction of the ground anchor had little effect on the foundation structures.

5. Conclusion

(1) the introduction of ground anchor shortens the eigen-period of the low-order vibration mode a little, the influence on the other mode is little; (2) the reduction of the response acceleration of the superstructure cannot be expected, but the response displacement is greatly reduced; (3) the shearing strains of the rubber bearings are largely reduced; (4) the responses of the pier column and the residual displacement are reduced greatly; (5) the influence on the foundation structures is little. The ground anchor reinforcement method is effective to improve the seismic performance of a girder bridge.