Evaluation on the Rotation Occurred on a Skew Bridge during the Wenchuan Earthquake

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1. Introduction

Wenchuan Earthquake, occurred on May 12th, 2008, had a magnitude of 8.0 by CEA. Maweihe Bridge, which is a 3-span, skew bridge, was damaged extensively in this earthquake. For verifying its movement behavior, dynamic analysis is conducted to study the collision and reflection phenomenon.

2. Objective Bridge

Drawing of objective bridge is shown in Fig. 1. It has a length of 39 m and a width of 10 m. The skewed angle reaches 50˚to the axis. The total bridge consists of three almost equaled spans, and the deck of each span consists of 8 hollow reinforced concrete slabs. Each slab is supported by four bearings. According to the field investigation, the bridge deck rotated in its entirety so that the bridge deck is considered as continuous girder.

3. Dynamic Analysis

Model in analysis was established based on the bridge structure and damage condition. A frame model is established for slab shown in Fig. 2 (a). Pounding and bearing spring is set for the abutment and bearing separately.

Shown in Fig. 2 (b), 8 pounding springs is set at each side as each span consists of 8 reinforced concrete slabs. The direction of pounding spring is set as perpendicular to the parapet, and the stiffness is set as 1.3 MN/mm based on punching shear experiment on RC member. Bearing spring is used to model the two types of bearing. Stiffness of bearing spring is set as 0.54 kN/mm. Wave data was measured by the Bajiao Station, which is the nearest station away from bridge. During the analysis, the wave is input in both X and Y direction in the same time. Since the wave was weak at start and end, data of 30 seconds in the middle of wave is used for the analysis.

Poundings happened at joint during the procedure of analysis. Three poundings happened in analysis which twice, shown in Fig. 3, at abutment A2 and once at abutment A1. Also the max value of pounding force gets 24.5 MN at the 2nd pounding.

Before the poundings, the deck kept translating in-plan with no rotation. Due to the rotational moment caused by the 1st pounding happened at joint, the deck began to have rotational acceleration shown in Fig. 4 (a). Rotational velocity began to increase during the 1st pounding shown in Fig. 4 (b). The

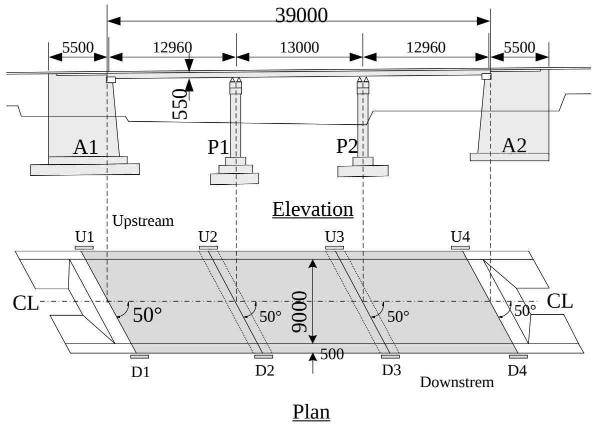
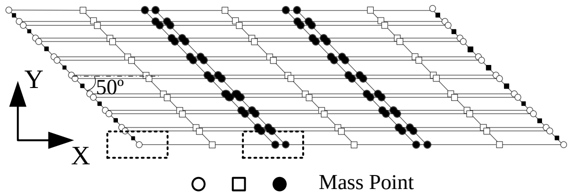
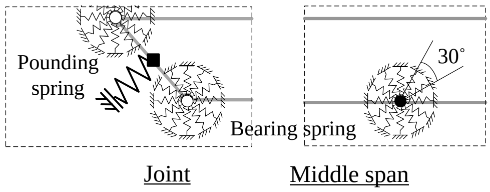


Fig. 1 Objective Bridge - Maweihe Bridge



(a) model of deck



(b) model of spring

Fig. 2 Analytical Model

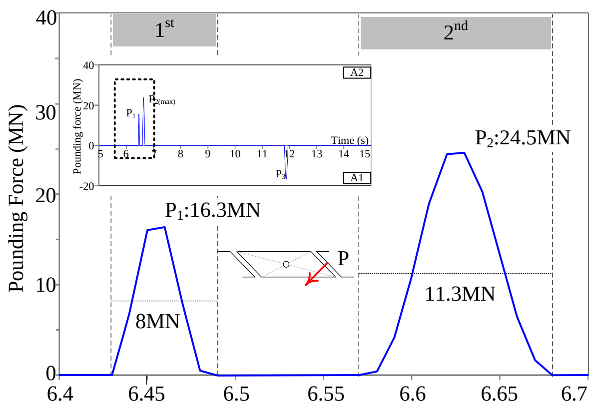


Fig. 3 Pounding Force History

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analytical rotational angle can be illustrated in Fig. 4 (c). During the 1st pounding, the rotational angle on deck increased by 0.01 deg. The rotational acceleration almost decreased to zero after the pounding so that the rotational velocity stayed almost steady. Meanwhile, the rotational angle kept increasing linearly until the 2nd pounding happened. Similarly, during the 2nd pounding, the rotational velocity had a sudden increase as the rotational acceleration increasing. Then the rotational angle continued to increase. The rotational angle totally increased by 0.07 deg in the 2nd pounding and continued to increase after the pounding.

As the rotation is mainly caused by pounding, mechanism of rotation can be illustrated in Fig. 5. With the pounding happened and the force arm, the deck will suffer a rotational moment. Based on the rotation theoretical equation, the rotational acceleration can be calculated by the rotational moment caused by pounding. Show in Fig. 5 (a), with pounding force of 16.3 MN and force arm of 10 m, the rotational moment by the 1st pounding is calculated as 163 MN·m. Illustrated in Fig.4 (a), the rotational acceleration can be calculated as rotational moment being divided by Moment of Inertia (named ‘I’ in the figure). Calculated value of the max rotational acceleration is 12 deg/s^2 (M_{P1}/I = 163/780*180/π) which is accord with the analytical one (error may due to the bearing). Similarly, the 2nd pounding also has been evaluated, and the error is also not so great. Consequently, pounding can be confirmed as the key factor causing the deck rotation. As for the increasing of rotational angle during each pounding, illustrated by the mechanism in Fig. 5 (c), the rotational angle has a positive correlation with the rotational moment and then being related to the pounding combined with the different duration of pounding integration Greater pounding will caused greater increasing of rotation.

Based on the mechanism supposed in Fig. 5, the Fig. 6 is plotted to confirm the main factor of rotational angle increasing. Here the average pounding force is used for evaluation as the pounding force keeps changing during the history show in Fig. 3. Based on the same impulse caused, the average pounding force can represent the magnitude of pounding during each pounding procedure. Illustrated in Fig. 6, increasing of rotation is related to the pounding. The greater pounding will caused the greater increasing of rotation during each pounding procedure

4. Conclusions

(1) Bridge deck keeps moving without rotation before the poundings. The 1st pounding gives the bridge a rotational acc. of 13.4 deg/s^2 and the rotational angle begin to increase. Pounding is the key factor causing the rotation of deck for skew bridge.

(2) Behavior of objective bridge accords to the basic physic rotation phenomenon as single axis. With greater pounding force and longer duration, the rotational angle of object will increase more, which 0.01 deg and 0.07 deg of increasing in rotation during the 1st and 2nd pounding separately.

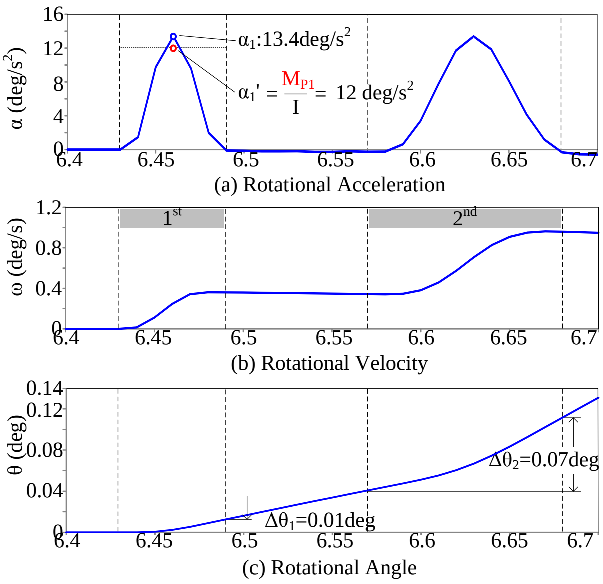

Fig. 4 Rotation History

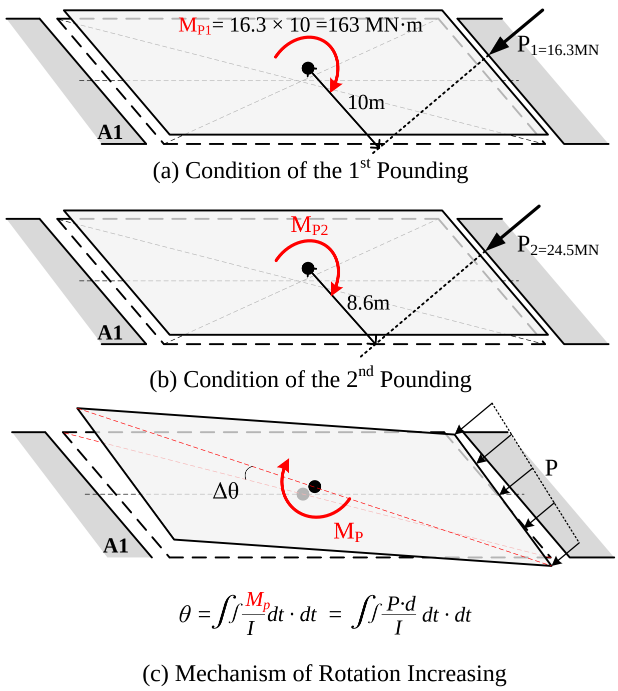

Fig. 5 Rotational Mechanism

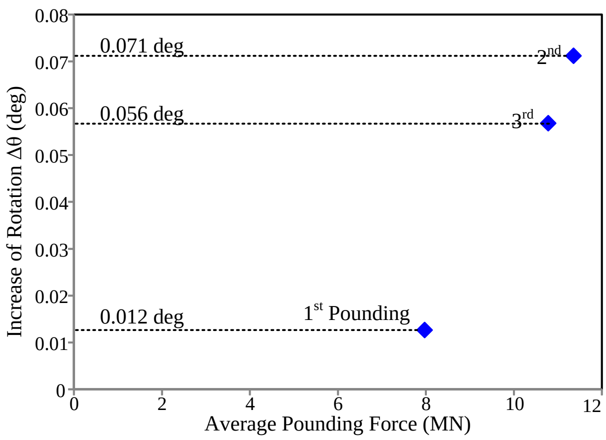

Fig. 6 Increasing of Rotation induced by Pounding