EFFECT OF BEARING LOCKING ON SEISMIC TORSION OF SKEWED BRIDGE PIERS

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1. INTRODUCTION

A skewed bridge deck possibly rotates around its vertical axis during an earthquake due to the collision with abutments or adjacent spans. This may subsequently induce the torsional rotation and twisting moment in skewed bridge piers. Furthermore, steel bearings may suffer damage during an earthquake and locking of bearing movement probably occurs. Impact force due to the locking after failure of bearing may result to the sharp increase of seismic torsion in bridge piers. In addition, flexural capacity and ductility of bridge piers also possibly decrease because of the existence of torsion. This paper presents the effect of locking of steel bearing on the seismic torsion in skewed bridge piers.

2. REPRESENTATIVE BRIDGE AND FINITE ELEMENT MODELLING

A 40-degree continuous skewed bridge as shown in Fig. 1 is analyzed here as the representative structure. The superstructure is composite type and has a weight of 25 MN. It is supported by three reinforced concrete piers and two abutments. Five fixed steel bearings (FB) are installed at the top of each pier and they do not allow the deck movement in longitudinal and transverse directions. Five movable steel bearings (MB) are also employed at the top of each abutment and they permit the deck movement only in longitudinal direction. In addition, cable restrainer systems are employed at both ends of this bridge. They are installed at the rightmost, center, and leftmost girders of the superstructure section along the longitudinal direction of bridge deck.

Both superstructure and substructure are modeled by beam elements as shown in Fig. 2. Takeda model is employed to the weak axis of pier section. The pier cracking torsional stiffness is assumed to be 20% of the full section. Restrainer systems and pounding between bridge deck and abutments are idealized by nonlinear spring elements as shown in Fig. 3. Fixed and movable steel bearings are modeled by a set of spring elements with the nonlinear hystereses as shown in Fig. 4. It is noted in Fig. 4(a) that sliding occurs between the upper and lower bearing after failure of the bearing. However, damage of a bearing is likely to lock the free sliding between the upper and lower bearing, so this mechanism is idealized by Fig. 4(b). The friction coefficients are assumed to be 0.15 and 0.10 in fixed and movable bearings, respectively. NS and EW components of the JMA Kobe ground motion are imposed to the longitudinal and transverse directions of bridge model, respectively.

Locking of the bearing after failure is assumed to occur in the longitudinal direction at one or two fixed bearings above P2. They are idealized by the model shown in Fig. 4(a) and (b). Four cases are investigated; 1) locking in rightmost bearing, 2) locking in leftmost bearing, 3) locking in rightmost and leftmost bearings, and 4) no locking.

3. EFFECT OF BEARING LOCKING

According to Fig. 5, it can be seen that the torsion in P1 of bridges with bearing locking is virtually the same to that of bridge without bearing locking. However, the maximum torsion in P2 of bridges with bearing locking is extremely larger than that of bridge without bearing locking. This is resulted from large eccentric impact forces (4.59 ~ 9.06 MN) due to bearing locking as shown in Fig. 6. Torsion in P2 of bridge with rightmost bearing locking is close to that of bridge with leftmost bearing locking. However, P2 of bridge with locking in both rightmost and leftmost bearings shows much lower torsion peaks compared to those of bridges with one locking bearing and torsion mostly occurs only in one direction. This is because of the cancellation of torsion from the same direction impact forces in both locking bearings.

4. CONCLUSIONS

1) Eccentric impact force due to locking of bearing sliding after failure of bearing can cause the significant increase of seismic torsion in skewed bridge piers.

2) The location of bearing locking is an important factor affecting the magnitude of torsion in bridge piers.

Key words: Seismic response, Bridge, Skewed bridge, Torsion, Bearing locking

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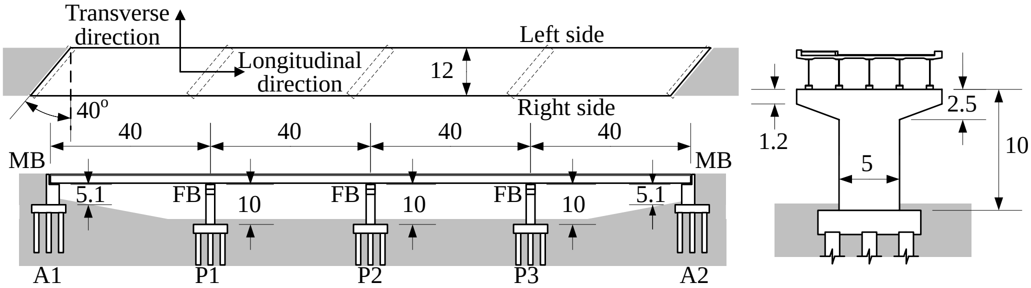


Fig. 1 Skewed bridge (Unit: meter)

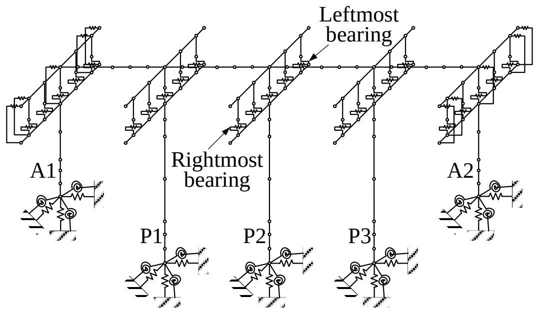
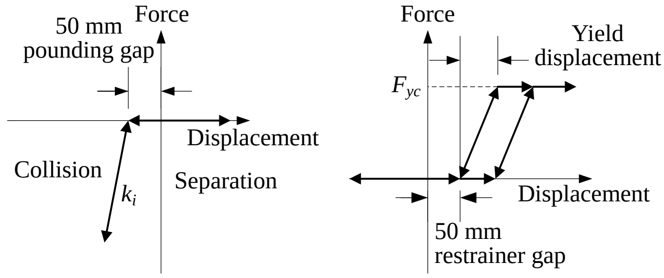
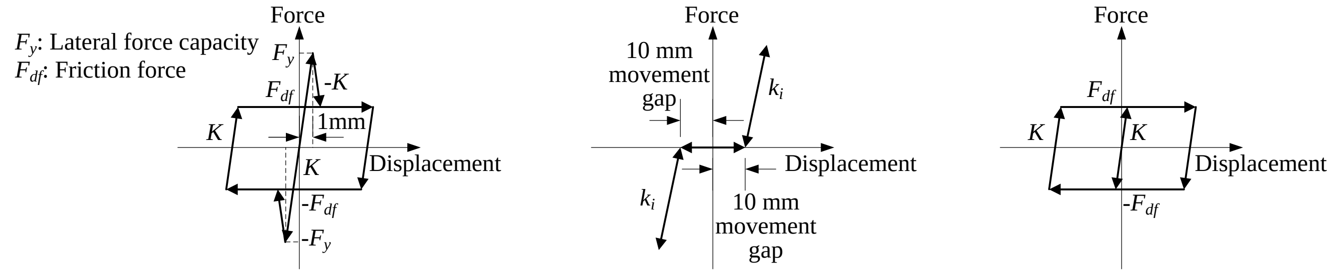


Fig. 2 Finite element modeling



(a) Pounding mechanism (b) Restrainer model

Fig. 3 Idealization on pounding and restrainer

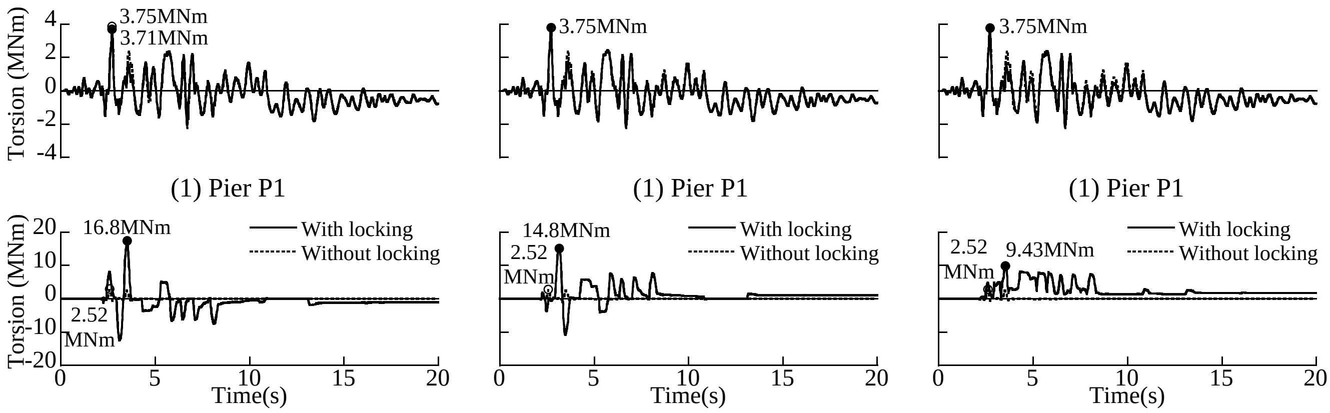


(a) Transverse and longitudinal directions of fixed bearing and transverse direction of movable bearing

(b) Model of locking after failure of bearing

(c) Longitudinal direction of movable bearing

Fig. 4 Nonlinear models for steel bearings

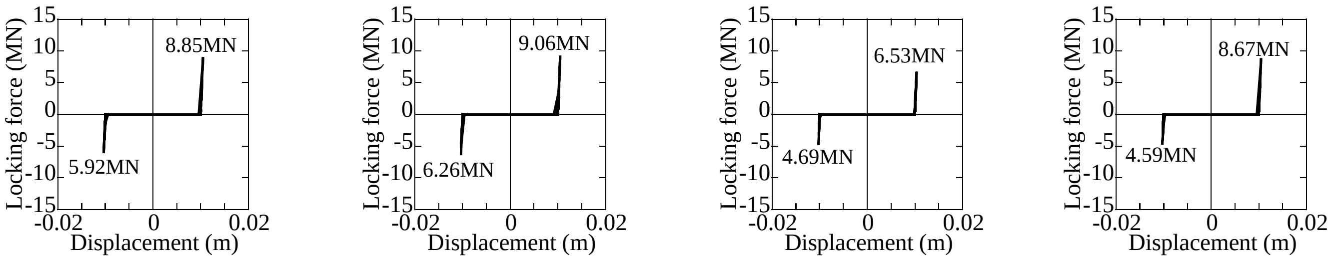


(1) Pier P1 (1) Pier P1 (1) Pier P1

(2) Pier P2 (2) Pier P2 (2) Pier P2

(a) Rightmost bearing (b) Leftmost bearing (c) Rightmost and leftmost bearings

Fig. 5 Effect of bearing locking on seismic torsion at P1 and P2



(1) Rightmost bearing (2) Leftmost bearing

(a) Rightmost bearing (b) Leftmost bearing (c) Rightmost and leftmost bearings

Fig. 6 Locking force vs. displacement hystereses of bearings