A 3D MODELING OF POUNDING FOR BRIDGE GIRDERS AND EXPERIMENTAL VERIFICATIONS

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Introduction

Unseating of bridge girders/decks during earthquakes is very harmful to the safety and serviceability of bridges. For a precise analysis of pounding effects, a 3D model is needed. This paper presents a model for 3D pounding problems of bridge girders with friction. Experiments of pounding have also been conducted to verify this model.

Modeling of Pounding [1)]

The problem considered herein is a general case of pounding by two bridge girders. As shown in Fig. 1, two girders contact with each other arbitrarily. They are referred as contactor body and target body where a contact happens between contactor node and target surface. A 3D contact-friction model for the problem is illustrated in Fig. 2. The target surface, named as *abcd*, is assumed as a rigid plane (The surface has not to be a rectangle). Vector **n** is the outer normal vector of the target surface. Node *k* is the contactor node at the contactor body, which penetrates into the target surface during contact. Point *p* is the physical contact point at the target surface *abcd*.

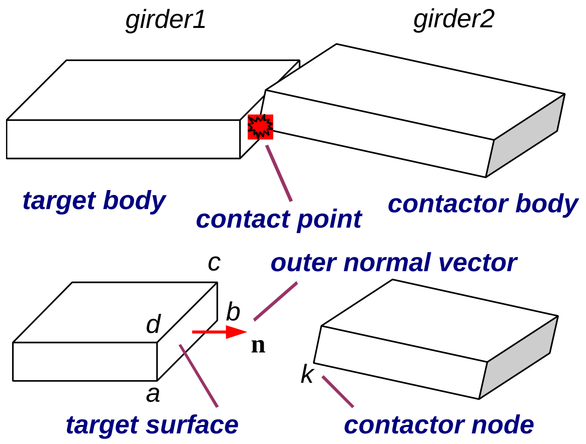

Fig. 1 Bridge girders in arbitrary contact

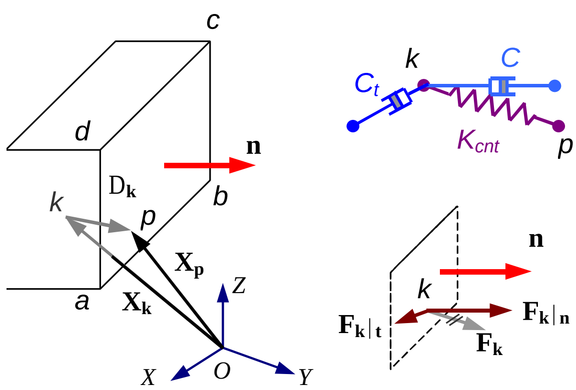

Fig. 2 Illustration of the 3D contact-friction model

The model utilizes material penetrations to compute forces during contact. Upon contact, a universal spring K_{cnt} between node *k* and point p is created to compute the force of contact. Two dashpots, *C* and C_t, are also applied to node *k* for simulating energy loss during contact. The contact force at node *k*, $\mathbf{F_k}$, can be computed as $\mathbf{F_k} = K_{cnt} \cdot \mathrm{D_k}$ and be divided into normal and tangent components ($\mathbf{F_k}|_\mathbf{n}$ and $\mathbf{F_k}|_\mathbf{t}$ respectively), where vector **n** is the outer normal vector of the target surface and vector **t** is a projection vector of $\mathbf{F_k}$ to the target surface. During contact, status can be divided into stick contact and slide contact which can be decided by the ratio of tangent component of the contact force $|\mathbf{F_k}|_\mathbf{t}|$ to the normal one $|\mathbf{F_k}|_\mathbf{n}|$. Contact forces can be calculated separately for stick and slide conditions.

Experimental Verifications

Experimental verifications were conducted for 1D and 2D cases with one model girder against an abutment[1), 2)]. For complicated cases of pounding between girders in 2D, new experiments of pounding between two model girders have also been conducted. The case is shown in Fig. 3(a). Each of the model girder weights 2 kg and the rubber supports under the model girders are in different heights. A sine wave is applied as an excitation with attack angle of 22.5°. Fig.

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3(b) illustrates the analytical model for the test. Two contactor nodes are applied to each girder where the edge of each girder is as a contact target surface. Results of displacements for each girder in longitudinal, transversal and rotational directions of 2D are given in Fig. 4. Good agreements at longitudinal and transversal directions can be seen. The main trends of pounding at rotating direction can also be simulated.

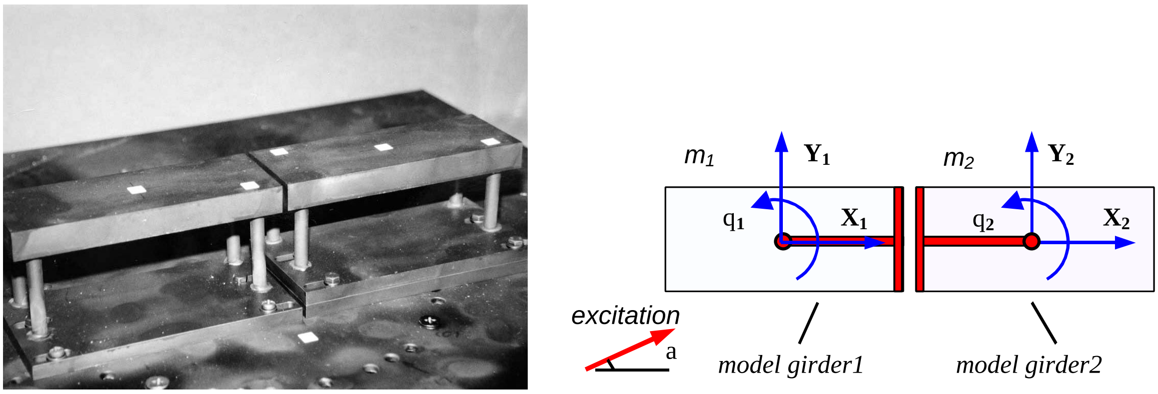
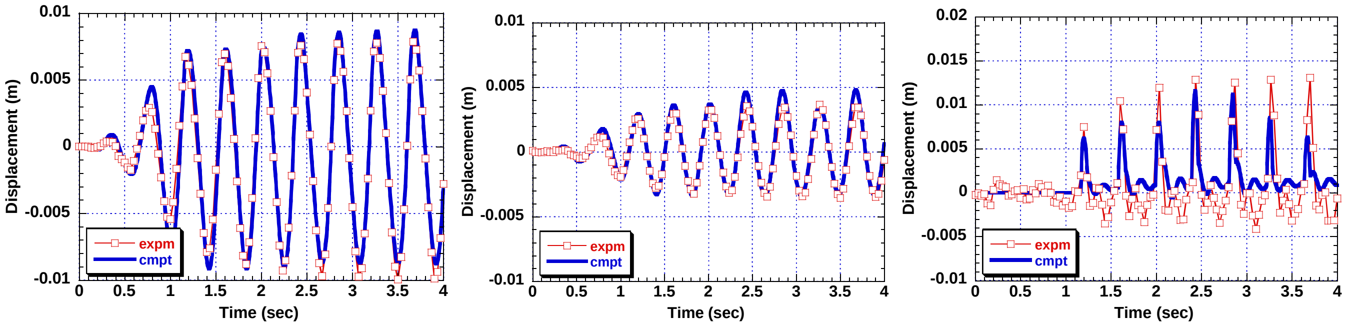
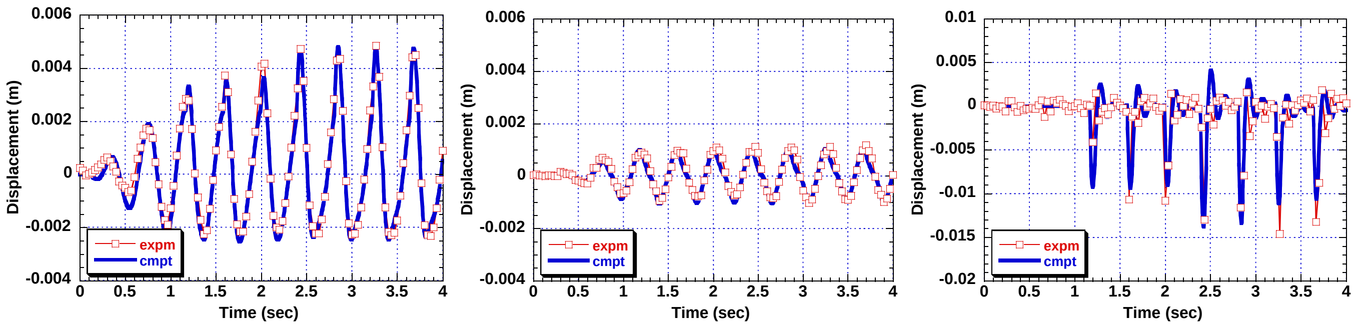


Fig. 3 (a) pounding between two model girders (b) analytical model



(a) m_1 – X displacements **(b) m_1 – Y displacements** **(c) m_1 – Rotating angles**



(d) m_2 – X displacements **(e) m_2 – Y displacements** **(f) m_2 – Rotating angles**

Fig. 4 Results of experiment and analysis (two girders, 2D case)

Conclusion

On considering pounding problems between bridge girders, a 3D contact-friction model has been developed. Experimental verifications have also been conducted. This model of pounding is suited to be combined with commonly used dynamic analysis methods. The applicability of this model is demonstrated by result comparison from experimental verifications.

Reference

1. Zhu P., Abe, M. and Fujino, Y., (2001), A 3D Contact-friction Model for Pounding at Bridges during Earthquakes, proceedings of The First M.I.T. Conference on Computational Fluid and Solid Mechanics, Cambridge, Massachusetts, USA.
2. Yanagino K., (2000), Modeling of Pounding Behavior of Bridge Girders under Seismic Excitations (in Japanese), Master's thesis, The University of Tokyo.