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Investigation on Phase Lag of Bidirectional Model in Nonlinear Seismic Analysis

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Abstract

The phase lag angle between the displacement and nonlinear restoring force vectors found in steel bridge piers under circular displacement loadings is one of the quantitative measures of multi-component interaction of bidirectional nonlinear restoring force. In this study, influence of the phase lag angle on dynamic response of structures under bidirectional seismic excitation is investigated using a modified rigid-plastic bidirectional restoring force model. The results of nonlinear time history analyses of the bidirectional rigid-plastic model with a uniform resultant force-displacement relationship and varying phase lag angles under bidirectional accelerograms show that the bidirectional model with a higher phase lag angle induces a higher circumferential energy dissipation, resulting smaller radial displacements.

Keywords: Phase lag; modified rigid-plastic bidirectional model; circumferential energy dissipation; bidirectional seismic response.

1 Introduction

Seismic performance assessment of bridges by means of nonlinear time history analysis using unidirectional spectrum-matched accelerograms is generally adopted in the design specifications of bridges in Japan [1]. Since actual earthquake ground motions are of bidirectional nature in the horizontal components, it can be assumed that the coupling of two horizontal seismic accelerograms affects the seismic response of bridges. In order to assure accuracy and reliability of seismic performance assessment of bridge piers, consideration of bidirectional interaction in the structural behavior is of great importance.

Liu and Igarashi [2] proposed that interpretation of the dynamic energy and the energy dissipation process in the nonlinear bidirectional seismic response with respect to the radial and circumferential components is an effective and relevant analytical approach to account for the properties of bidirectional seismic response. Results of nonlinear bidirectional analyses of a circular steel bridge pier show that the level of the circumferential component of energy dissipation caused by the motion perpendicular to the radial direction effectively contributes to dissipation of the total kinetic energy, resulting in the reduction of the maximum bidirectional response.

The phase lag angle between the restoring force vector and the displacement vector of the bidirectional structural model under prescribed circular bidirectional displacement paths is introduced as a quantitative measure of the circumferential energy dissipation. The properties of the multiple shear spring (MSS) model using the concept of the phase lag angle, in particular the radial displacement dependency of the phase lag

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