Research Project Highlight

Influence of Vertical Ground Shaking on Design of Bridges Isolated with Friction Pendulum Bearings

Project # 1134-NCTRRY

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Start-End Dates:
12/15/2017-12/14/2018

Abstract
The objective of this seed project is to answer the question: "Should vertical ground shaking be explicitly considered in the design of bridges with friction pendulum bearings?" The project builds on prior NEES/E-Defense testing that demonstrated both experimentally and numerically that vertical shaking can increase both the base shear and the story accelerations in buildings isolated with triple pendulum bearings. Vertical shaking introduces a high-frequency variation in bearing axial force that is transmitted to the base shear and can excite higher structural modes. More complete understanding is needed to develop sensible guidelines for including this effect in design. Application to bridges, due to their relative simplicity, is an ideal starting point to develop a holistic understanding of the influence of vertical shaking on relevant response quantities.

A simplified bridge model will be developed and computational simulations performed to understand the influence of vertical ground shaking on bridge response as a function of key system parameters. The model will capture the vertical vibration of the superstructure spans, which is accomplished through element discretization and distributed mass. A parameter study will be conducted to understand how the base shear varies with increasing vertical shaking intensity. The bridge seismic response will be evaluated by response history analysis using OpenSees, under a suite of ground motions that best represents high vertical seismicity (V/H ratio of 1.2). Isolation bearings will be modeled using Single Friction Pendulum Bearing or Triple Friction Pendulum elements, which use friction models to simulate the interaction of bearing axial force and lateral force. Increase in base shear and other effects for 3D shaking relative to 2D shaking will be evaluated, focusing on systematic trends that can be justified by fundamental engineering principles. A small project Advisory Board will be assembled to provide input in the design of the parameter study.

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Deliverables
A PEER report documenting the analysis, results and conclusions, and recommendations of whether or not vertical shaking should be explicitly considered in the design of bridges with friction pendulum bearings.

Research Impact
Performance-based design techniques are used for critical infrastructure that have seismic performance objectives beyond minimum code requirements. Highway bridges are a critical component of resilient transportation systems that support post-earthquake response and recovery. Seismic isolation techniques are recognized as an effective option to reliably achieve high post-earthquake performance objectives such as continuous operation. The influence of vertical shaking on the lateral response of systems with friction pendulum bearings has been identified as a potential shortcoming that may prevent achievement of envisioned performance objectives targeted through PEER performance-based earthquake engineering methodology. However, prior research has shown that the influence of vertical shaking can be reliably predicted through properly constructed models and analysis techniques. In this project, a thorough parameter study will lead to more complete understanding of the significance of vertical shaking on isolated bridges with a variety of response characteristics, and may ultimately lead to recommended changes in the design of bridges isolated with triple pendulum bearings. If it is concluded that vertical shaking should be considered, then follow-up work is anticipated to determine the specifics of design guidelines for seismically isolated bridges. Efforts to determine specifics should be driven by interaction and feedback with code committees, such as AASHTO or Caltrans.

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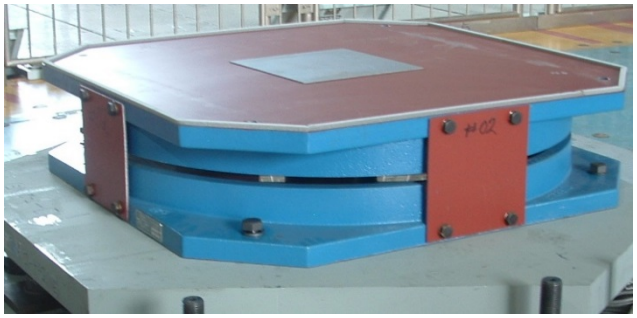
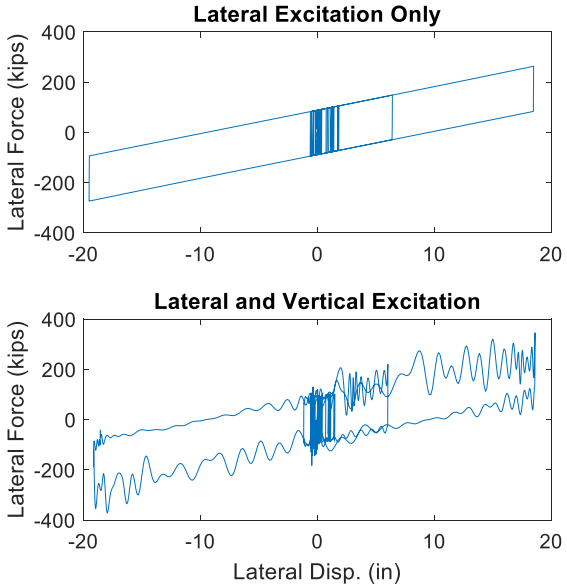
Project Image





Triple pendulum bearing (left), and representative isolator force versus displacement for a single degree-of-freedom system with friction pendulum bearing, with and without (strong) vertical shaking (right)

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