Consistent omnidirectional extension of uniaxial nonlinear hysteretic response models

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Wednesday, June 27
Introduction

Seismic isolation systems have found broad use in the design of critical buildings. Triple friction pendulum (TFP) bearings are among state-of-the-art technology in isolation devices which exhibit highly nonlinear/hysteretic responses. In seismic response simulations biaxial lateral responses are often required.

The same situation is encountered in the seismic response simulation of pile foundations. In such cases, the typical approach is to use two uncoupled macro-elements that represent the uniaxial lateral response of the pile in two lateral directions.
Motivation

Such uses of two uncoupled macro-elements in two orthogonal directions will produce various errors. Both the direction and the amplitude of the resultant reaction will be incorrect in general and will depend on the chosen orientation of the macro-elements—i.e., the same displacement history will produce different reaction force histories for different macro-element assembly orientations.
We propose a methodology rooted in classical plasticity, which takes any uniaxial backbone curve and produces a biaxial model that will consistently reproduce the original uniaxial response in any arbitrary direction.

The particular multi-surface plasticity framework adopted here is due to Montáns who aimed at describing the Masing behavior of various materials. This model was able to describe the multiaxial nonlinear hardening function in a relatively simple way which is highly suitable for modeling the hysteretic behavior of TFP bearings as well as soil-pile interaction.
Application to TFP Bearings

Controlled-displacement experiments aimed at characterizing the bidirectional behavior of TFP bearings were conducted at UC Berkeley in 2011.

Comparison of measured response curves with those predicted by the calibrated omnidirectional model are presented here only for the butterfly orbit. As these results indicate, the agreement between test data and the omnidirectional model is very good.
Application to Soil-Pile Interaction

Due to lack of experimental data, Varun and Asimaki simulated the biaxial response of an elastic pile embedded in a cohesionless inelastic soil using a three-dimensional continuum finite element (FE) model.

Results are shown in the left figure, where it can be seen that the omnidirectional model captures the FE results. The predictions from multi-surface plasticity model have captured the soil-pile reaction with good accuracy, while providing a consistent bi-axial coupling.

Comparison of hysteretic $p$-$y$ curves from Varun and Asimaki’s 3D FE model (left) and our omnidirectional model (right) for an eight-shaped biaxial cyclic loading orbit (Note: the “Model” results shown on the left figures are the calibrated omnidirectional Bouc-Wen model results by Varun and Asimaki)
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**Today Poster Session:**

- **Time:** 5:15 – 7:00 pm
- **Room:** Pasadena (Exhibit Hall)
- **Poster location:** Number 004