Wells and Caprocks
Dynamic Shaking

Keurfon Luu, Preston Jordan, William Foxall, Jonny Rutqvist

Task Description/Goals/Outcomes

This task aims to assess the dynamic response of wells subject to an earthquake-induced excitation. In this work, we analyze the characteristics of a casing system to understand how they influence wellbore loading.

The end objective is to model response of wells in terms of bending moment for a sufficiently large number of models for the development of fragility (probability of failure) functions for OpenSRA.

Introduction

The response of the casing systems to a seismic ground motion is strongly nonlinear and usually requires dynamic simulations to correctly account for the nonlinear structural behavior of the piles.

We implemented the Beam on a Nonlinear Winkler Foundation (BNWF) model into the open-source finite-element code OpenSeesPy v3.3 (McKenna 2011; Zhu et al., 2018) where ground motions are applied as boundary conditions to the springs' supports to account for the resistance of the soil.

We used the code SHAKE91 to generate depth-dependent acceleration time histories for a vertically propagating seismic wave in a horizontally layered medium.

Model

The BNWF approach is a simplified model where piles are modeled as a series of beam elements attached to nonlinear springs to represent the nonlinear pile-soil interaction. In our OpenSees model, the different casings (conductor, surface and production) and the tubing are modeled using Force-based Beam-Column elements.

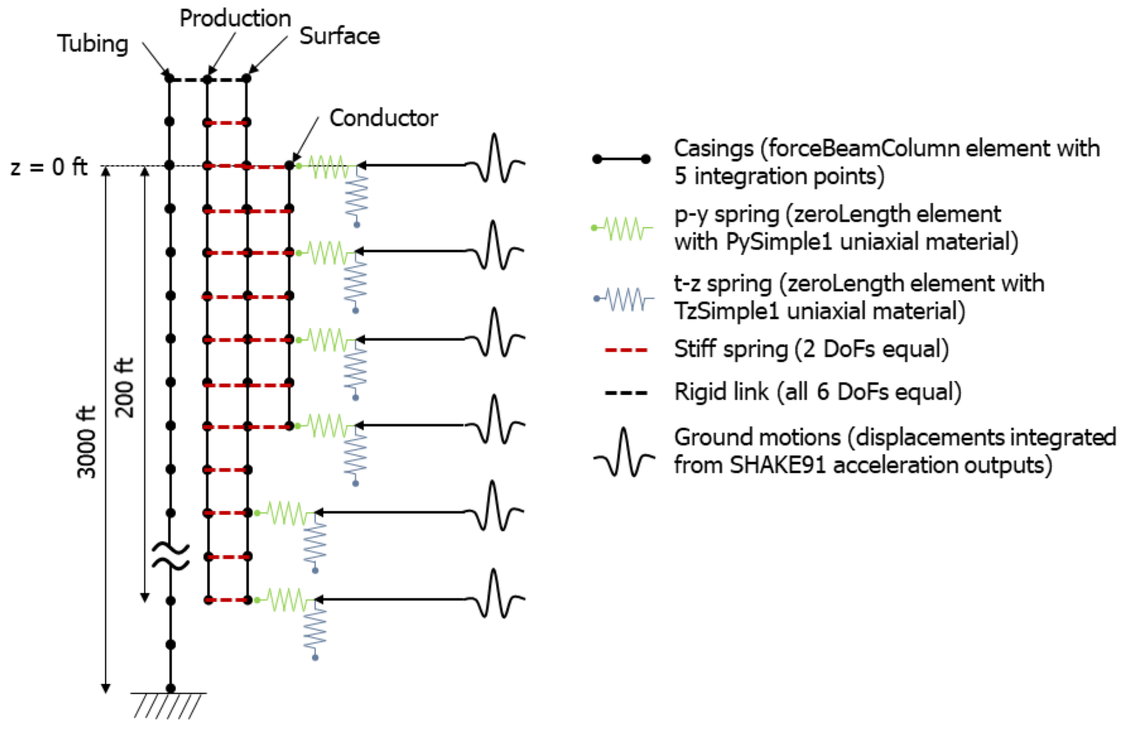

Figure 1. Finite-element conceptual model used in OpenSees

Results

We first performed a sensitivity analysis and determined that the maximum bending moments recorded along the casing system are primarily affected by the angle of internal friction of the soil, the height and mass of the wellhead.

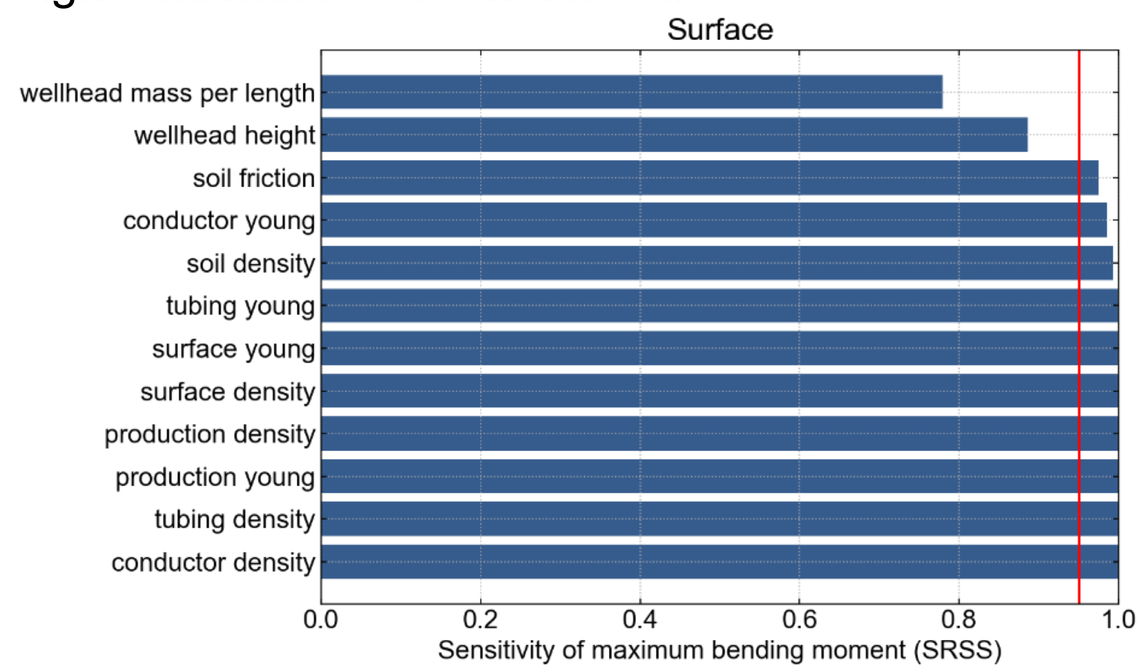

Figure 2. Example results of sensitivity analysis for the surface casing (Mode 4)

In order to sample the parameter space for all the ground motions and well configurations considered in this work, we drew a set of 100 Latin Hypercube parameter samples. A total of about 40,000 simulations have been performed. A second order multivariate polynomial function is fitted to the calculated maximum bending moments using the key model parameters and the PGA as variables to develop the fragility functions.

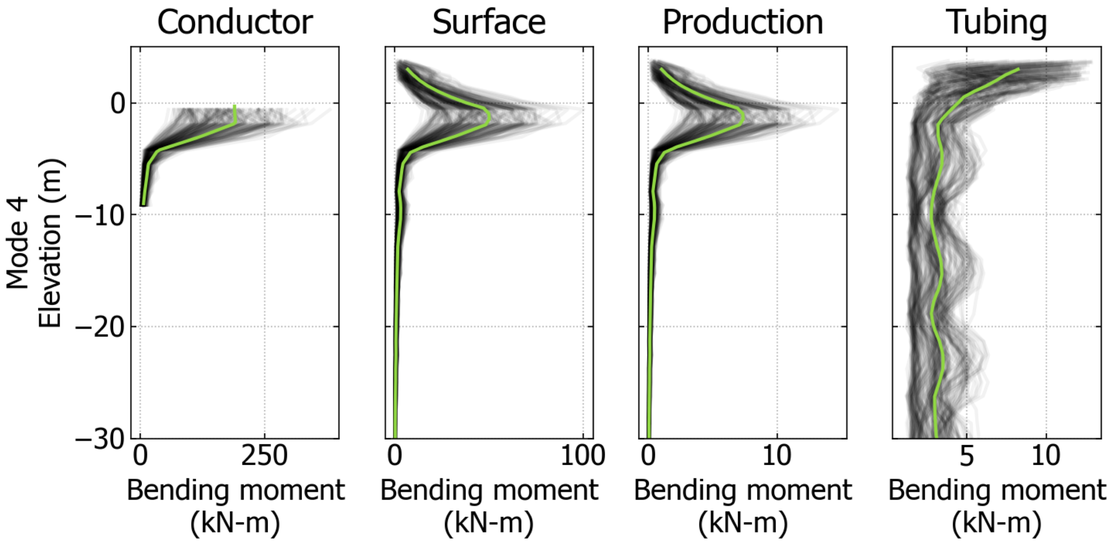

Figure 3. Example results of seismic loading analysis for mode 4 of well configuration.

FUNDING PROVIDED BY THE CALIFORNIA ENERGY COMMISSION

Workshop Poster Session
January 11, 2023