Abstract

The use of rocking mechanisms has the potential to improve the resilience of the next generation of earthquake resistant structures. To better understand their earthquake response and to provide an analytical basis for improved assessment and design methods, this thesis investigates the fundamental dynamics of flexible rocking structures.

The response of flexible rocking structures to earthquakes is explored with new analytical models derived from first principles. The proposed analytical models describe flexible structures rocking freely on rigid ground during earthquakes. These models avoid the limitations posed by earlier investigations by considering large rotations, detailed superstructure models and the interaction of impact forces with superstructure vibrations. To further inform accurate modelling strategies, shake table experiments were conducted. These experiments provide new data that allows in-depth investigation of modal characteristics of the structure during rocking. Additionally, the experiments quantify the sensitivity of rocking response to differences in energy dissipation and energy transfer to vibrations at impact. This sensitivity leads to variable experimental response to near-identical table motions, highlighting the difficulty in achieving reliable estimations of rocking response during an earthquake.

Using the validated analytical models, a general fundamental understanding of the dynamic response of flexible rocking structures is formulated. This is achieved by characterizing the lateral displacement and force demands during earthquakes. Initially, the dynamic response of idealized models of flexible rocking structures, rigid rocking structures and linear elastic oscillators are compared. The comparisons reveal the distinct dynamic characteristics of flexible rocking structures. Then, further analyses on the earthquake response of flexible rocking structures yield two main results. First, the displacement demands during pulse type earthquakes are due to large velocity pulses which sufficiently describe the rocking response of large flexible structures. The displacement demands during non-pulse type earthquakes are typically smaller but more difficult to predict due to sensitivities of motion. It is suggested to investigate displacement demands using a probabilistic framework. Second, the vibration characteristics and excitation mechanisms change significantly during rocking. These changes are prominent for lower vibration modes which are partially isolated from the ground motion effects. However, the same modes are significantly excited as a result of rapid force direction reversal at impact.

The aforementioned fundamental results pave the way for improved analysis and design methods for flexible rocking structures. In particular, assessment methods proposed in

this study, such as the dimensionless demand maps and the modal decomposition approach can be effective. The former can be used to determine large displacement demands due to velocity pulses whereas the latter provides the basis for an appropriate consideration of force demands during rocking.