# Preliminary Assessment of Site Response Analysis for Vertical Ground Motions: Case Study of Free-Field Downhole Array at KKNPP

Ramin Motamed[1], Austin Metz[2], Ibrahim Almufti[3]

Extensive research on how to characterize site-specific horizontal ground motions at the ground surface through Site Response Analysis (SRA) has been carried out over the last several decades. The well-established current practice is to use either the equivalent linear approach or the non-linear method for SRA with only horizontal ground motions. Several computer programs have been developed with different levels of complexity and reasonably successful validations have been achieved (Stewart et al. 2008). However, SRA for vertical ground motions is not yet fully understood and research on this topic is limited.

Although the large majority of structural damage due to seismic shaking has been attributed to the horizontal component of ground motion, compelling data has been gathered to implicate large vertical ground motions as a significant contributor to structural damage (e.g. Papazoglou and Elnashai 1996; Abdelkareem and Machida 2000; Diotallevi and Landi 2000; Bradley 2012; Makan et al. 2013).

This study was motivated to improve our understanding of vertical SRA by a growing body of evidence which suggests that vertical ground motions play a key role in structural and especially nonstructural damage. Structural design codes are expected to eventually incorporate an expanded number of cases where vertical shaking is required to be explicitly considered, especially for structures with continued functionality performance objectives.

During the 2007 earthquake in Niigata-ken (M6.6) in Japan, strong ground motions were recorded at the free-field downhole Service Hall Array (SHA) at the Kashiwazaki-Kariwa Nuclear Power Plant (KKNPP). Previous research (Motamed et al. 2016) by the authors proposed an improved methodology to model nonlinear soil response at large strains and demonstrated that Finite Element (FE) program LS-Dyna has the ability to accurately model bi-directional horizontal ground response at this site. The measured ground motions during the 2007 earthquake at the SHA are unique with respect to the amplitude of observed accelerations at the ground surface in the horizontal (PGA of 0.38g) as well as in the vertical (PGA of 0.39g) directions. This study is focused on evaluating a physics-based SRA for vertical ground motions using LS-Dyna similar to the one for the horizontal motions and evaluate the numerical predictions using the SHA downhole data. This is an on-going project and our preliminary simulations have produced promising results which will be presented at this meeting. This presentation will further discuss the advantages and limitations of physics-based SRA for vertical ground motions and highlight the key differences with the conventional SRA for the horizontal ground motions.

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[1] Assistant Professor, Department of Civil & Environmental Engineering, University of Nevada Reno, Email: motamed@unr.edu, Phone: 775-784-6960
[2] Graduate Student, Department of Civil & Environmental Engineering, University of Nevada Reno
[3] Associate, Arup, San Francisco