



Centrifuge and 3D FEM Modeling of the Effect of Tunneling in Fault Zone in Reverse Fault-Foundation Interaction

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Abstract The presence of underground structures within fault zones has the potential to alter deformation patterns on the ground surface, thereby placing existing structures—typically regarded as safe—at risk. This paper presents findings from four centrifuge model tests and 3D numerical simulations exploring the effects of tunneling in fault zones. This study investigated the values associated with foundation rotation, surface deformations, and the patterns of fault rupture propagation through various soil strata. The results demonstrate that the presence of a tunnel alters the interaction pattern between fault rupture and foundation systems, which can lead to an increase in foundation rotation. Notably, the findings indicate that a precise consideration of superstructure shape can enhance foundation rotation by up to 23%. Furthermore, the presence of a tunnel in the fault zone causes substructures to endure major damage from vertical fault displacements exceeding 0.6 m. In

contrast, these substructures experienced similar levels of damage at vertical fault displacements of 1.7 m in the absence of tunnels.

Keywords Fault rupture · Foundations · Tunnels · Interaction · Centrifuge modeling

1 Introduction

Observations after huge earthquakes such as Kocaeli and Duzce (Turkey, 1999), Chi-Chi (Taiwan, 1999), Wenchuan (China, 2008), and Kumamoto (Japan, 2016) revealed that permanent ground deformations due to fault movements can cause serious damage to surface and subsurface structures (Bray 2001; Yu et al. 2016; Kiyota et al. 2017). In this regard, structural seismic design codes recommend avoiding construction in the vicinity of active faults (Hart et al. 1999; Boncio et al. 2018). Avoiding construction across or near active faults is not possible for long structures, such as tunnels, bridges, and pipelines.

Fault rupture studies initiated with a review of free-field analyses and the interaction between fault rupture and foundations. Interaction between fault ruptures and shallow foundations has been investigated using field evidence (Bray 2001; Anastopoulos and Gazetas 2007; Faccioli et al. 2008), experimental modeling (Bransby et al. 2008a, b; Moosavi et al. 2010; Ashtiani et al. 2016; Yao and Takemura 2019) and numerical analysis

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