



Seismic Assessment of Deep Tunnel in Near Fault Ground Motion

Bhavesh Banjare¹, Swetha Veeraraghavan²

¹Research Scholar, Dept. of Civil Engineering, IISc Bangalore

²Assistant Professor, Dept. of Civil Engineering, IISc Bangalore

Abstract

Underground tunnels are an essential part of transportation and utility networks, and their vulnerability to earthquakes has significant socio-economic impacts. Tunnels have suffered substantial damage in past earthquakes, including the 2008 Wenchuan (China) earthquake, the 1995 Kobe (Japan) earthquake, the 2004 Niigata (Japan) earthquake, and the 1999 Chi-Chi (Taiwan) earthquake. Past studies on the 2D plane strain analysis of tunnel cross-sections subjected to vertically propagating seismic waves provide essential insights on the racking and ovaling of the tunnel cross-section during an earthquake. However, during the recent 2008 Wenchuan (China) earthquake, tunnels located near earthquake faults suffered damage not just to the cross-section but also in the longitudinal direction, which previous 2D studies cannot explain. The primary reason for the failure of the 2D studies in these near-fault scenarios is because the wave field near the fault is much more complex than a simple vertically propagating seismic wave. Therefore, a 2D plane strain approximation of the problem considering only the tunnel cross-section subjected to a uniform vertically propagating seismic loading in the out-of-plane direction is no longer valid in this case. The present study aims at understanding the coupled longitudinal and transverse response of underground tunnels subjected to obliquely incident (with respect to tunnel axis) seismic waves. The wave fields are generated through earthquake fault rupture simulations using earthquake faults with different dip angles. The numerical simulation of the soil-tunnel system is conducted using the open-source finite element software called MASTODON, developed by Idaho National Laboratory. Four different earthquake fault rupture scenarios for 2D and 3D are considered for this study. Analysis results reveal that the seismic responses of the tunnels increase with the increase in dip angle up to a fault dip of 45°. Additionally, the results showed that the 3D model needs to be considered for more general earthquake scenarios to capture both in-plane and out-of-plane responses (bending and cross-sectional changes) of the tunnel structure during the seismic loading.

Keywords: Underground tunnels, Seismic analysis, Soil-structure interaction, Seismic wave propagation, Longitudinal seismic response