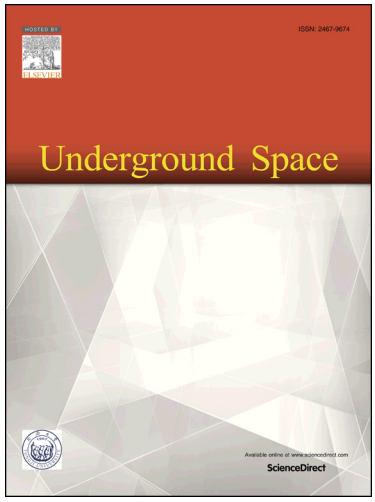

Impact of Seismic Design on Tunnels in Rock - Case Histories

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Impact of Seismic Design on Tunnels in Rock - Case Histories

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Abstract

The tunnel industry has considered that tunnels, especially tunnels in rock, are naturally resistant to earthquake action, including faulting, shaking, deflection and ground failure. As the number of case histories of tunnels subject to earthquake action has increased, the industry has started to recognize that, although tunnels in rock have good resistance against earthquakes generating peak ground accelerations (PGA) lower than 0.5g, it is important to include the dynamic forces and displacements generated by seismic ground motions in the design process to obtain a more reliable design. These additional earthquake forces impact the final design, potentially requiring changes to the ground support and additional reinforcement of the concrete lining, as illustrated by case histories presented in this paper

Introduction

The tunnel industry considered that tunnels were naturally resistant to earthquake action for many years, as they did not experience the same high levels of shaking as surface structures. This perception was supported by the relative good historic performance of tunnels and underground structures, especially of tunnels in rock, during large earthquakes. Dowding and Rozen 1978 presented one of the first compilations of damage to rock tunnels due to earthquake shaking. They collected information on 71 tunnels and compared their behavior with estimated peak ground accelerations (PGAs) and peak ground velocities (PGVs). Their conclusions can be summarized as follow:

- Collapse of tunnels from shaking occurs only under extreme conditions.
- No damage occurred when PGAs were lower than 0.19g and/or PGVs were lower than 0.2 m/s
- Minor to moderate damage occurred when PGAs were up to 0.5g and PGVs up to 0.9 m/s
- Moderate to heavy damage occurred when PGAs were larger than 0.5g
- Tunnel collapse only occurred associated with movement of an intersected fault.
- Tunnels are much safer than above ground structures for any given event

Several additional reviews of tunnel performance during earthquakes have been published since Dowding and Rozen 1978, including Powers et al. 1998, and being particularly important the reviews performed after large earthquakes in Taiwan (Wang et al. 2001), Japan (Yashiro and Kojima 2007, Kosugi et al. 2011), and China (Lin & Chai 2008). These additional data points have confirmed that