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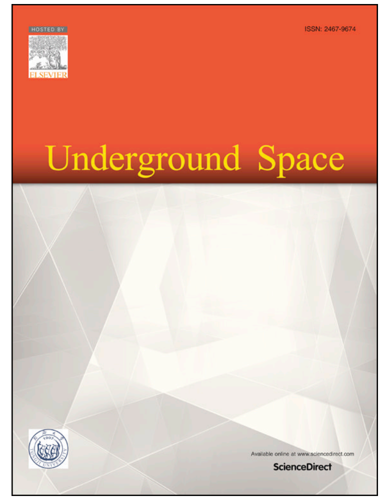

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SEISMIC ANALYSIS OF LONG TUNNELS: A REVIEW OF SIMPLIFIED AND UNIFIED METHODS

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Abstract: Seismic analysis of long tunnels is important for safety evaluation of the tunnel structure during earthquakes. Simplified models of long tunnels are commonly adopted in seismic design by practitioners, in which the tunnel is usually assumed as a beam supported by the ground. These models can be conveniently used to obtain the overall response of the tunnel structure subjected to seismic loading. However, simplified methods are limited due to the assumptions that need to be made to reach the solution, e.g. shield tunnels are assembled with segments and bolts to form a lining ring and such structural details may not be included in the simplified model. In most cases, the design will require a numerical method that does not have the shortcomings of the analytical solutions, as it can consider the structural details, non-linear behavior, etc. Furthermore, long tunnels have significant length and pass through different strata. All of these would require large-scale seismic analysis of long tunnels with three-dimensional models, which is difficult due to the lack of available computing power. This paper introduces two types of methods for seismic analysis of long tunnels, namely simplified and unified methods. Several models, including the mass-spring-beam model, and the beam-spring model and its analytical solution are presented as examples of the simplified method. The unified method is based on a multiscale framework for long tunnels, with coarse and refined finite element meshes, or with the discrete element method and the finite difference method to compute the overall seismic response of the tunnel while including detailed dynamic response at positions of potential damage or of interest. A bridging scale term is introduced in the framework so that compatibility of dynamic behavior between the macro- and meso-scale subdomains is enforced. Examples are presented to demonstrate the applicability of the simplified and the unified methods.