Protection of Underground Utility Tunnel Contents from Transversal Earthquake Effects

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Abstract. This research explores strategies for mitigating transversal seismic effects on the contents of utility tunnels. To evaluate interactions between the tunnel and its contents, a low-dimensional mechanical model was developed. In this model, the tunnel cross-section is assumed to be rigid, interacting with the surrounding soil, which is modelled as a compressive-only medium. The content is placed on a frame structure, also treated as rigid, and connected to the tunnel through flexible devices that provide partial isolation between the contents and the tunnel. An hysteretic mass dampers is considered to limit the displacement of the isolated frame relative to the tunnel.

Introduction

The expansion of underground utility tunnels to centralize essential pipelines for water, gas, electricity, and communications reduces surface disruption and aids maintenance, especially in urban areas. Historic assumptions that underground structures are safer than above-ground buildings have been challenged by significant damage in events like the 1995 Kobe earthquake. While tunnel resilience has been studied extensively, research into the seismic protection of internal pipelines remains limited. Earthquakes can damage pipelines within tunnels in two main ways. The first involves longitudinal seismic effects on the pipelines [1], while the second pertains to transversal seismic effects [2]. This study focuses on the latter, specifically investigating vibration isolation strategies for pipelines within utility tunnels with an emphasis on transverse isolation. A low-dimensional mechanical model is employed to capture tunnel-content interactions under transversal seismic excitation. The tunnel is considered to be infinitely long, so the analysis is confined to a representative cross-sectional plane.The tunnel cross-section is assumed to be rigid, requiring three displacement parameters to describe its kinematics. The surrounding soil is modelled as a compressive-only medium. The pipelines are fixed to an internal frame, also considered rigid, which permits only horizontal displacement relative to the tunnel due to the use of flexible connectors between the frame and the tunnel Consequently, the internal frame-pipeline system requires one additional displacement parameter. A hysteretic mass dampers, modelled as one-dimensional mechanical systems, is attached to the internal frame to limit its horizontal displacement relative to the tunnel. Altogether, the system is represented by a five-dimensional mechanical model (see Fig.1).

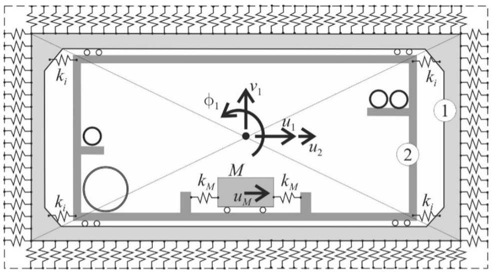

Figure 1: Underground tunnel (1), oscillating internal frame (2), and mass damper.

Results and Discussion

An extensive parametric analysis was performed by exciting the system with several recorded earthquake excitations. Absolute acceleration at key points within the tunnel with the isolated internal frame was measured and compared to acceleration at the same points in a tunnel without internal isolation. A significant emphasis was devoted to studying the nonlinear dynamics of the system, exploring how coupling the internal frame with nonlinear oscillators can beneficially reduce the internal absolute acceleration. The results demonstrated the effectiveness of the internal isolation of the contents and the nonlinear mass dampers in enhancing the seismic response of the entire tunnel-content system. **Acknowledgement**. This work is funded by the European Union - Next Generation EU, Mission 4 Component 2 Investment 1.1, in the framework of the project PRIN 2022 PNRR, "P2022ZT5X5 - Smart Under-Ground Infra-Structures for Secure Communities and Post-Disaster Emergency Response: Eco-Friendly Seismic Protection Solutions" (CUP: E53D2301762 0001, University of L'Aquila).

References

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