

Mitigation of Transversal Seismic Effects on Underground Utility Tunnel Systems

Simona Di Nino¹, Manuel Ferretti¹, Lorenzo Mancini¹, Angelo Di Egidio¹,

¹*Department of Civil, Construction-Architectural and Environmental Engineering,
University of L'Aquila, 67100 L'Aquila
E-mail: simona.dinino@univaq.it, manuel.ferretti@univaq.it, lorenzo.mancini3@univaq.it, angelo.diegidio@univaq.it*

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Utility tunnels are underground passages designed to house and protect essential infrastructure such as water pipes, electrical cables and gas lines. They are commonly found in large cities, airports, and industrial complexes. Consequently, underground structures have become increasingly common in recent years. While utility tunnels are generally better protected than above-ground structures, they remain vulnerable to seismic events, which can cause significant damage. Recently, numerous dynamic tests and numerical simulations have been carried out to enhance tunnel seismic performance [1]. More importantly, it is essential to investigate the seismic response of the entire utility tunnel system, rather than the tunnel structure alone, with particular attention to the vibration behavior of the internal pipelines (e.g., [2]).

This study presents an analytical model for assessing the seismic protection of utility tunnel contents. The tunnel cross-section is idealized as a rigid body in a compression-only elastic soil, with internal frames partially isolated by four visco-elastic devices. Additional control is provided by a Hysteretic Mass Damper Inerter (HMDI) connected to the frames. The low-dimensional model is validated against a finite element (FE) benchmark, showing good agreement and suitability for rapid parametric evaluations and preliminary design. Harmonic analyses assess dynamic sensitivity and quantify control effectiveness. Time-domain simulations with representative earthquakes highlight system performance under realistic seismic conditions.

References

- [1] Hashash, Y.M., Hook, J.J., Schmidt, B., and Yao, J. I.C., “Seismic design and analysis of underground structures”, *Tunnelling and underground space technology*, **Vol 16**, page 47–293 (2001).
- [2] Li, J., Zhong, Z., Bi, K., and Hao, H., “Seismic fragility assessment of utility tunnel and internal pipeline system”, *Tunnelling and Underground Space Technology* **Vol 158**, page 106441 (2025).

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