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Shortcomings of the Winkler model in the Assessment of Sectioned Tunnels under Seismic Loading

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A Winkler model is often applied to the design of tunnels subject to seismic loading, and in spite of its simplicity it has been found to provide reasonable results. However, the Winkler model significantly underestimates the stiffness at the joints in sectioned tunnels. According to the present analysis, this leads to an over prediction of the joint openings resulting in a conservative design. A case study is carried out for an immersed six-lane road tunnel in Thessaloniki, Greece. It consists of eight tunnel elements, each with a length of approximately 150 m and connected by Gina gaskets. The seabed is stratified with three layers of sandy and clayey soil over bedrock, and an earthquake acceleration time series recorded from the 1995 Aegion event is applied as input. Horizontal input motion is assumed at the bedrock, and a one-dimensional wave-propagation model transfers the vibrations to the ground surface as horizontally polarised shear waves. The incoherency of the ground vibration along the tunnel is modelled by an apparent propagation velocity of 1500 m/s, and the wavefronts impinge on the tunnel at an angle of incidence equal to 45°. The response obtained using the Winkler model is compared with the results of a full three-dimensional finite-element model of the tunnel and the surrounding soil. The analysis is carried out in the time domain, using ABAQUS/Standard. The displacements at the sides and bottom of the computational mesh are prescribed, corresponding to the free-field vibrations of the stratum in the absence of the tunnel, *i.e.* based on the assumption that the tunnel has an insignificant impact on the response in the far field. Analyses show that the Winkler model provides openings at the gaskets of more than 200 mm. The corresponding result of the continuum finite-element model is 20 mm, *i.e.* an order of magnitude lower. However, if the joints are not included in the two tunnel models, nearly identical results are obtained. Hence, it is concluded that the Winkler model is useful for continuous tunnels with a homogeneous cross section, but it should be used with extreme caution for the design of sectioned structures. In order to obtain a reliable prediction of the relative motion between two tunnel elements, a computational model must account for the stiffness of the ground and not only the stiffness included in the Winkler model.

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