Postprint: Analytical Analysis of Longitudinal Seismic Response of Shield Tunnels Considering Axial Force Effects

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Abstract

How to reasonably estimate the seismic response of shield tunnels has always been a research focus in both industry and academia. Compared with the transverse seismic response, the longitudinal seismic response of shield tunnels is more complex. Treating the shield tunnel as a Timoshenko beam on a Winkler foundation and considering the influence of axial force, including residual axial force and longitudinal seismic additional axial force, a theoretical calculation model for the combined action of longitudinal and transverse ground displacements is proposed, and the longitudinal seismic response of shield tunnels is solved through the finite difference method. Based on a conventional 6.2m-diameter shield tunnel with staggered joint assembly for case verification, considering the influence of axial force enhances the overall stiffness of the shield tunnel, and both internal force and deformation responses are reduced; if the influence of axial force is not considered, the model can degenerate into the traditional calculation method. Furthermore, through parametric sensitivity analysis, the influence laws of tunnel residual axial force, subgrade reaction coefficient, seismic wave incidence angle, and wavelength on the longitudinal seismic response of shield tunnels are investigated. The results indicate that: the larger the residual axial force, the greater the improvement in overall stiffness of the equivalent beam, and the smaller the seismic response of the shield tunnel; and when the incidence angle is less than 45°, the influence of residual axial force on the tunnel seismic response is more significant. The larger the subgrade reaction coefficient, the greater both the overall deflection of the tunnel and the local discontinuous deformation between rings; seismic waves with wavelengths in the range of 20m~100m are more likely to cause large opening and dislocation between tunnel ring joints. The above research results can provide theoretical support for the longitudinal seismic design of shield tunnels.

Full Text

Preamble

Theoretical Analysis for the Longitudinal Seismic Response of Shield Tunnel by Considering Axial Force

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Abstract

How to reasonably estimate the seismic response of shield tunnels has always been a research hotspot of concern in both industry and academia. Compared with the transverse seismic response, the longitudinal seismic response of shield tunnels is more complex. This study models the shield tunnel as a Timoshenko beam on Winkler foundation, considering axial force effects—including residual axial force and additional longitudinal seismic axial force—to develop a theoretical calculation model for the combined action of longitudinal and transverse ground displacements, which is solved using the finite difference method. Taking a conventional 6.2m diameter staggered-joint assembled shield tunnel as a case study, the results show that considering axial force effects enhances the overall stiffness of the shield tunnel, thereby reducing both internal force and deformation responses; if axial force effects are neglected, the model degenerates to the traditional calculation method. Furthermore, parametric sensitivity analysis is conducted to investigate the influence patterns of tunnel residual axial force, foundation reaction coefficient, seismic wave incident angle, and wavelength on the longitudinal seismic response of shield tunnels. The results indicate that larger residual axial forces lead to greater enhancement of the equivalent beam' s overall stiffness and consequently smaller seismic responses of the shield tunnel, with this effect becoming more pronounced when the incident angle is less than 45°. A larger foundation reaction coefficient results in greater overall tunnel deflection and larger localized discontinuous deformation between rings, while seismic waves with wavelengths in the range of 20m~100m are more likely to cause significant opening and dislocation at tunnel ring joints. The above research findings can provide theoretical support for the longitudinal seismic design of shield tunnels.

Keywords: shield tunnel; longitudinal seismic response; Timoshenko beam; finite difference solution

Note: Figure translations are in progress. See original paper for figures.