Analytical Method for Seismic Analysis of Shaft-Tunnel Junction under Longitudinal Excitations

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Abstract : Shaft-tunnel junction is a typical case of the structural nonuniformity in underground structures. The shaft and the tunnel possess greatly different structural features. Even under uniform excitations, they tend to behave discrepantly. Studies on shaft-tunnel junctions are mainly performed numerically. Shaking table tests are also conducted. Although many numerical and experimental data are obtained, an analytical solution still has great merits of gaining more insights into the shaft-tunnel problem. This paper will try to remedy the situation. Since the seismic responses of shaft-tunnel junctions are very related to directions of the excitations, they are studied in two scenarios: the longitudinal-excitation scenario and the transverse-excitation scenario. The former scenario will be addressed in this paper. Given that responses of the tunnel are highly dependent on the shaft, the analytical solutions would be developed firstly for the vertical shaft. Then, the seismic responses of the tunnel would be discussed. Since vertical shafts bear a resemblance to rigid caissons, the solution proposed in this paper is derived by introducing terms of shaft-tunnel and soil-tunnel interactions into equations originally developed for rigid caissons. The validity of the solution is examined by a validation model computed by finite element method. The mutual influence between the shaft and the tunnel is introduced. The soil-structure interactions are discussed parametrically based on the proposed equations. The shaft-tunnel relative displacement and the soil-tunnel relative stiffness are found to be the most important parameters affecting the magnitudes and distributions of the internal forces of the tunnel. A hinge-joint at the shaft-tunnel junction could significantly reduce the degree of stress concentration compared with a rigid joint.

Keywords : analytical solution, longitudinal excitation, numerical validation , shaft-tunnel junction