Spectral Analysis of Structures under Vibration due to Underground Moving Trains on Curved Route

Abstract

The movement of underground trains on tracks creates vibrational waves which pass through the rail, tunnel and soil and reach the ground surface and structures around the rail route. When the train reaches the curvature of the track, the track becomes asymmetric, as well as the reaction forces applied to the wheels of the train, and as a result of the suspension system interactions. This inconsistency may lead to an increase or decrease in the vibration caused by it, which is of great importance and needs to be investigated. In spite of the fact that created waves do not damage surrounding structures due to having small magnitudes and amplitudes, they can be a problem for non-structural elements, sensitive facilities and building occupants. In this research, in order to study these problems, the spectral diagrams of the horizontal acceleration responses alongside the rail route are calculated and presented. Moreover, the spectral diagrams of the acceleration responses which are perpendicular to the movements of structures with one degree of freedom are illustrated which are mainly due to the curvature of the rail routes. Maximum structural responses of the tunnel and soil systems to the vibration waves under moving loads can be obtained in different environmental conditions at minimum time. In order to achieve this objective, different available trains from all over the world were evaluated and three standard trains were selected according to their details including: wheels, bogies and suspension systems. The dynamic load exerted on the rails was calculated and extracted as a wheel reaction by the software. Moreover, the interaction between soil and the tunnel under the dynamic load of the train was simulated as a three dimensional model. After dynamic analyzes of the model with finite element method, horizontal and vertical responses and related spectral diagrams of acceleration responses are extracted. These diagrams are plotted for three types of depths, three types of soils, three types of trains, and two different speeds in the route curvature for each type of train. The results illustrate that the horizontal spectral acceleration response alongside the route, and the spectral vertical response of structures are directly proportional to the type and velocity of the trains and the route curvature. These responses have inverse proportions with the wave speed in the soil and the depth of the tunnel. Assuming that other variables are constant, responses decrease between 1 to 60 percent by increasing tunnel depth. As the velocity of shear wave increases by hardening the soil, the responses decrease by 2 to 90 percent. As the train speeds up, the responses increase significantly which varies from 20 to 90 percent. Furthermore, after analyzing 54 different models, acceleration responses exceeded the tolerable threshold for humans in 41 cases as the tolerable threshold is 5.5 percent of the gravity acceleration.