
On the Suitability of Elastic Foundation Models

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Abstract

Elastic foundation models are extensively used to idealize the track substructure beneath the rail beam. These models, at the cost of certain simplifications, offer the advantage of being computationally inexpensive and are thus more likely to be used in engineering practice. This paper investigates the suitability of the elastic foundation models for predicting the deflection response of the rail track systems subjected to motion induced dynamic loading. A generalized track model which incorporates the effects of all essential structural and sub-structural track components-sleepers, rail-pads, ballast, and sub-ballast-is considered. Two different approaches are followed to model the subgrade. In the first approach, the subgrade layer is modeled using a viscoelastic element whose stiffness is derived from the properties of the underlying soil medium. A time domain deflection analysis of this so-called elastic foundation model is subsequently carried out to evaluate the rail beam deflections under the moving train loads. In the second approach, the soil medium beneath the track model is modeled as a semi-infinite elastic media. For this case, the deflection results are obtained in the time domain using a numerically stable, wavenumber based analytical approach. The rail beam deflections for both the models are evaluated for different train velocities using the track parameters associated with the high-speed railway line along two different sites for which data is available in the open literature: (a) a soft soil site in Sweden and (b) a stiff soil site in Portugal.

The results show the comparisons of rail beam deflections obtained from the considered track models with the experimental data recorded at these sites. It is found that at lower train velocities (70-120 kmph) both models adequately capture the gross rail-track behavior at both sites. Further, at higher train velocities (180-220 kmph), the elastic foundation model shows reasonable agreement with the measured deflection values for stiff soil site, however, underestimates the deflections observed at the soft soil site. On the other hand, deflection results of the model comprising the semi-infinite elastic media are seen similar to the experimentally observed profile for both the sites.

The underestimation in the deflection magnitudes in case of elastic foundation model may be attributed to the inability of the constituent viscoelastic element to consider the inertia- and wave-propagation related effects associated with the soil medium. The semi-infinite elastic

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media, on the other hand, is capable of incorporating those effects of the soil medium and thus, captures the deflection behavior even at higher train velocities. It is additionally shown that in general the magnitude of the experimental value of the critical velocity in the case of the soft soil site is appreciably lower (due to the associated lower wave propagation velocity) than that predicted by the elastic foundation model. However, at the 'rock-type' sites, these pair of velocities may be of comparable magnitude, and thus, the elastic foundation model may prove suitable in these circumstances.

Keywords: Railway track, Elastic foundation models, Dynamic load, Analytical model