ABSTRACT

High-speed rail transportation requires careful design of a rail track. The design of a railway track is governed by the load-bearing capacity and maximum possible speed of transportation. The capacity of a high-speed rail tracks is generally limited by its critical speed. It is the speed at which the vibration occurs at the largest magnitude. Thus, its identification is necessary to prevent derailments and damage to the rail tracks.

The present study attempted a three-dimensional finite element analysis of a typical ballasted rail track under a single moving wheel load at different speeds to evaluate the critical speed and to assess the dynamic impact factors at subcritical speeds. Dynamic impact factor (DIF) is the ratio of dynamic and static wheel load. It determines the effect of dynamic load (mostly under subcritical speeds) on a rail track based on several empirical formulations given in the literature. These formulations are developed under a low-speed range of about 50 km/h on old tracks. Thus, their reliability for rail tracks under higher speeds up to 200 km/h needs to be validated. The study continues to a moving load analysis on a ballasted rail track resting over different geometric combinations of the geosynthetic reinforced earth (GRE) embankment and retaining wall to analyse the effect of reinforcing agents on embankment section configurations, including their approximate construction cost. The present study also covers preliminary work on moving load finite element analysis on embedded track system (ETS) model, which is a ballastless rail track system.

Ballast, subballast, and subgrade layers of the track were modelled as elastoplastic ma-

terial with material damping and radiation damping (infinite layers). Track response were calculated in the form of stress, displacement, velocity, and acceleration responses. Different parameters were analysed for suitability towards finding the critical behaviour, such as the method of applying moving load, material model of primary load-carrying layer (ballast), effect of boundaries, and the track responses extracted from the output databases. Parametric studies were performed on material damping and stiffness of track substructure layers to see their effect on the track's dynamic response. The effect of shear strength parameters (cohesion and friction) of the subgrade was also analysed to examine their effect on the critical behaviour of the rail track.

For the assessment of dynamic impact factors, the motion of a pressure-loaded areal patch was simulated using the VDLOAD subroutine in ABAQUS. Parametric studies on train speed, track modulus, and wheel diameter were performed. Regression analysis was performed on the finite element results, and a DIF formulation was developed as a function of speed and track modulus. The study shows that a combination of vertical velocity, stress, and acceleration trends can be used to identify the critical speed of the rail track, which was found as 350 km/h for the present study. It was found that the Young's moduli of substructure did not show direct proportionality with the critical speed. The damping ratio has a small effect over the critical speed, while the increase in shear strength of the subgrade increases the critical speed.

Regarding the DIF assessments, it was inferred that the difference between the existing DIF formulae and the present study increases with speed. The relationship calculated from the numerical study suggested a higher DIF than the existing relationships in the literature. At higher speeds (>150 km/h), the elastoplastic behaviour of the rail track causes higher vibration as compared to lower speeds (<50 km/h) where dynamic vibrations are generally

under elastic range.

The analysis of GRE structures under moving load showed that the ground acceleration decreases by 50 % with geosynthetics and facing walls in the speed range of 100 to 400 km/h. It was also inferred that the bulk mass of earthen embankments is not enough to counter large vibrations. The study on ballastless ETS model suggested that the stiffness and thickness of concrete bearing layer will affect the rail track response the most.