Slab Track Behaviour under Train Passage and Hammer Impact — Measurements at Different Sites and Calculated Track Interaction with Continuous Soils

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This contribution intends to give an overview on the vibration behaviour of slab tracks in comparison of measurements and calculations and also by comparison of different track types at more than ten different measuring sites. In theory, tracks on continuous soil are calculated by the frequency-wavenumber domain method. In experiment, geophone measurements are transformed to displacement results. Two aspects of track behaviour are considered, the frequency-dependant compliance of the track, measured by hammer impact, and the deflection under a passing axle load. In theory, the response to a single axle can be calculated, whereas in experiment, only the passage of the whole train can be measured. For comparison of theory and experiment, the calculated deflection under a single axle is superposed to get the response of the whole train. As a result, the slab track characteristics are completely different from the ballast track characteristics where each axle can be seen in the time histories. The slab track has a more global behaviour where only a whole bogie can be found in the track response and moreover, the two neighbouring bogies are not completely separated. The measurement of the different track elements (rail, sleeper, track plate, base layer) and the frequency-dependant compliances with possible resonances yield further information about the properties of the track elements. The calculations show that the soil has the dominant influence on the amplitudes and the width of the track-plate displacements. In the measurement results, the following parameters are analysed: slab track vs. ballast track, different types of slab tracks, damaged slab tracks, different trains, switches at different measuring points, voided sleepers, an elastic layer, the mortar layer, and different soils at different places. Finally, a good agreement between measured and calculated results is found for the normal and some special (damaged, floating) slab tracks.

NOMENCLATURE

\( a \) width of the track
\( D \) damping (of the rail pad)
\( EI \) bending stiffness
\( f \) frequency
\( F \) force
\( F' \) force per track length
\( G \) shear modulus of the soil
\( H_S \) compliance of the soil for a plane wave
\( H_{ST} \) compliance of the track-soil interface for wave along the track
\( k_R \) stiffness of the rail pad
\( K' \) stiffness matrix of the elastic track elements
\( K_S \) dynamic stiffness matrix of the soil
\( K_T \) dynamic stiffness matrix of the track
\( K_{TS} \) dynamic stiffness matrix of the track-soil system
\( l_B \) axle distance in a bogie
\( l_{BP} \) distance of two neighbouring bogies
\( m' \) mass per length
\( p_i \) wavenumber transform of the uniform force distribution across the track
\( t \) time
\( t_P \) thickness of the track plate
\( u \) displacement
\( u^T \) displacement vector
\( v_S \) shear wave velocity of the soil
\( v_T \) train speed
\( x \) coordinate across the track
\( y \) coordinate along the track
\( \omega \) circular frequency
\( \xi_x \) wavenumber in across the track
\( \xi_y \) wavenumber along the track

1. INTRODUCTION

Slab track is a track form which becomes increasingly important in railway traffic. Slab track is an alternative track form to the ballast track. The ballast is replaced by a stiff layer which usually is a concrete plate (Fig. 1). By that, the settlement of the ballast is eliminated and the maintenance effort should be reduced. Many lines have been built with slab tracks worldwide but there are still attempts to improve this track form.

The dynamic behaviour of slab tracks is useful for many aspects of railway engineering. Modelling and theoretical results are necessary for the design.\(^1\) The load condition of any track is an important information for understanding the deterioration\(^3\) and for maintenance decisions.\(^4\) Track monitoring\(^5\) can be used to prevent damage.\(^6,7\) Dynamic measurements can be used to identify track damage\(^8,9\) or general track characteristics.\(^10,11\) The soil has a strong influence on the slab track behaviour so that the analysis of the substructure\(^12-14\) has a great value, particularly at transition zones.\(^11,15,16\)