Modeling of lateral sleeper-ballast interaction on rail track

Jeniffer Barreto and José Varandas

Universidade Nova de Lisboa-Faculdade de Ciências e Tecnologias, Lisboa, Portugal

jc.barreto@campus.fct.unl.pt, jnsf@fct.unl.pt

1 Introduction

The lateral resistance of the track is an important factor for the good behavior of the track, contributing for the non-derailment of the train when subjected to lateral forces. These forces can be, the action of centrifugal forces in a curve, the cross wind, a seismic excitations or dynamic lateral forces due to hunting oscillation. The objectives of this work are to: (i) study the relation between the lateral stiffness and the vertical force applied, (ii) study the influence of the soil foundation stiffness on the lateral stiffness and, (iii) study the influence of the lateral sleeper-ballast interaction on the stress distribution in the ballast.

2 Methods

A matlab program was developed by Varandas (2013) and applied in this study. The program uses the finite element method and allows 3D dynamic analyses incorporating the non-linear material behavior of the granular layers of ballast and sub-ballast using a resilient behavior model (K-θ), and the non-linear contact between the sleepers and the ballast (penalty formulation). (Varandas 2013)

3 Results

Vertical and horizontal loads were applied on the central sleeper of the model under the rail, as show in Figure 1. Tables 1-3 present the adopted parameters values of the tests, as well as the considered loading regimes.

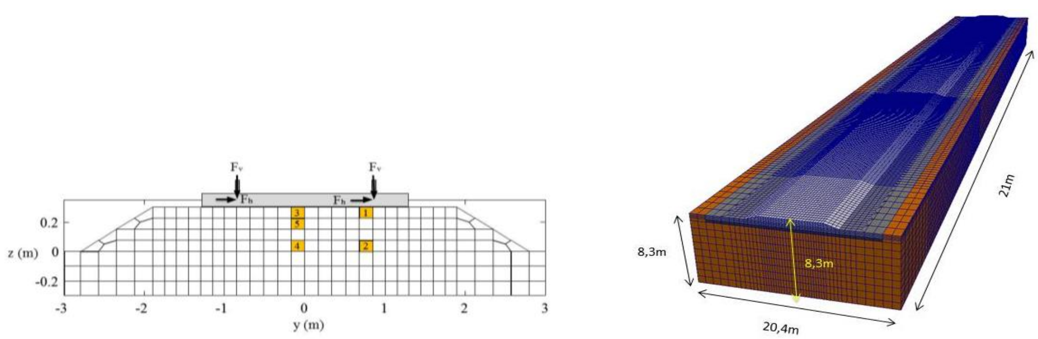

Figure 1-Model geometry and elements in study

Test	Soil layer 1: E[mPa] - ν - ρ:	Soil fundation : E[mPa] - ν - ρ	F_z [kN]	F_y [kN]	K_y [kN/mm]	K_z [kN/mm]
A9	200 - 0,35 - 1,8	20 -0,45- 2	-75	25	41,9	20,0
B9	200 - 0,35 - 1,8	60 - 0,3 - 2	-75	25	61,0	36,2
C9	200 - 0,35 - 1,8	100 - 0,3 -1,68	-75	25	70,1	50,6
D9	200 - 0,35 - 1,8	150-0,35-1,8	-75	25	76,0	70,1
E9	200 - 0,35 - 1,8	200 - 0,35 - 2	-75	25	79,8	83,3
F9	200 - 0,35 - 1,8	300-0,3-2,04	-75	25	84,8	99,7

Table 1-Soil foundation analysis

Test	Soil layer 1 : E[mPa] - ν - ρ	Soil fundation : E[mPa] - ν - ρ	F_z [kN]	F_y [kN]	K_y [kN/mm]	Kz [kN/mm]
D1	200 - 0,35 - 1,8	150 - 0,35 - 1,8	1	8	34,5	-2,0
D2	200 - 0,35 - 1,8	150 - 0,35 - 1,8	0	8	35,7	0,0
D3	200 - 0,35 - 1,8	150 - 0,35 - 1,8	-1	8	37,0	1,9
D4	200 - 0,35 - 1,8	150 - 0,35 - 1,8	-8	8	44,9	13,6
D5	200 - 0,35 - 1,8	150 - 0,35 - 1,8	-10	8	46,8	16,5
D6	200 - 0,35 - 1,8	150 - 0,35 - 1,8	-16	8	51,6	24,4
D7	200 - 0,35 - 1,8	150 - 0,35 - 1,8	-24	8	56,7	33,5
D8	200 - 0,35 - 1,8	150 - 0,35 - 1,8	-40	8	64,6	48,0

Table 2-Load analysis

	Test 1	Test 2	Test 3	Test 4
$K_{c,h}$[kN/m^2]	0	1x10^2	1x10^4	1x10^6
F_z[kN]	-75	-75	-75	-75
F_y[kN]	0	0	0	0
Soil Fundation	D	D	D	D

Table 3-Lateral interaction between sleeper-ballast analysis

Table 1 shows the tests performed to study the influence of the soil foundation, where the applied load remains constant. Table 2 shows the tests performed to study the influence of the vertical load, where in this case the soil foundation remains unchanged. Table 3 shows the tests performed to study the influence of the lateral sleeper/ballast contact stiffness, $K_{c,h}$ on the stress distribution when only vertical loads are applied.

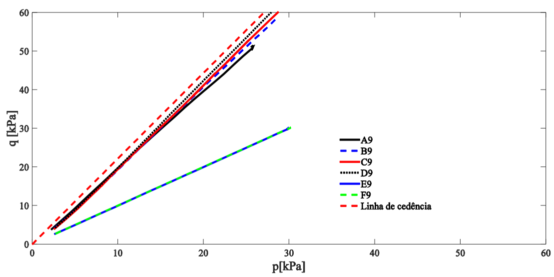

Figure 2- p-q for loads analysis

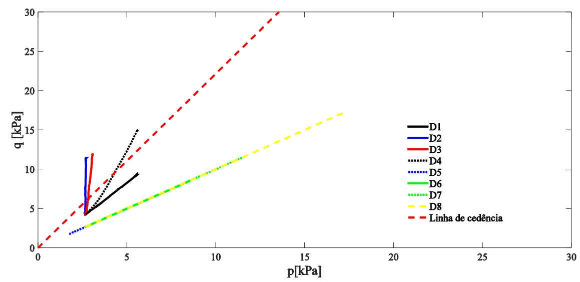

Figure 3- p-q for soils foundation

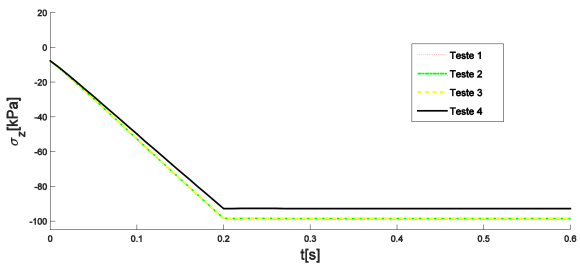

Figure 4- Evolution in time of the vertical stress

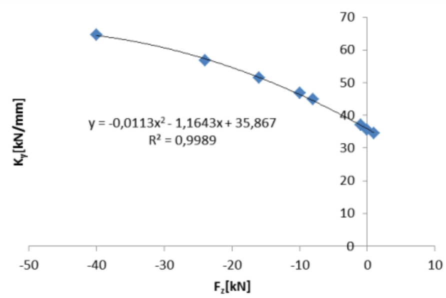

Figure 5- F_z-K_y relation

The tests were analyzed in terms of mean normal stress- p, and deviatoric stress- q, as show in Figures 2 and 3 and in terms of vertical stress, σ_z as show in Figure 4.

4 Conclusions

In the soil foundation study, as expected, it was observed that the higher the Young modulus of the soil the higher the lateral stiffness. For the load study, Figure 5 presents the obtained vertical load (F_z) - lateral stiffness (K_y) relation, being nonlinear due to the adopted constitutive model for the ballast. Also it is possible to see in Figure 3 that for higher F_y/F_z relation, the graph p-q lies above the failure line. In the study of the influence of the lateral interaction, $K_{c,h}$ on the stress distribution, it is noted that the parameter $K_{c,h}$ has a non negligle influence on the obtained stresses inside the ballast layer, therefore denoting the importance of a care representation of this friction interface in studies focused on the top granular layers of the track.

5 References

Varandas, J. N. S. (2013). *Long-term behavior of railway transitions under dynamic loading application to soft soil sites.* PhD Thesis-Universidade Nova de Lisboa-Faculdade de Ciências e Tecnologias

Barreto, Jeniffer (2016). *Modelação da interação lateral balastro-travessa em vias-férreas.* Master Thesis (submitted)- Universidade Nova de Lisboa- Faculdade de Ciências e Tecnologias