3rd ICTG 2016
04-07 September 2016, Guimarães, Portugal

Modeling of lateral sleeper-ballast interaction on rail track

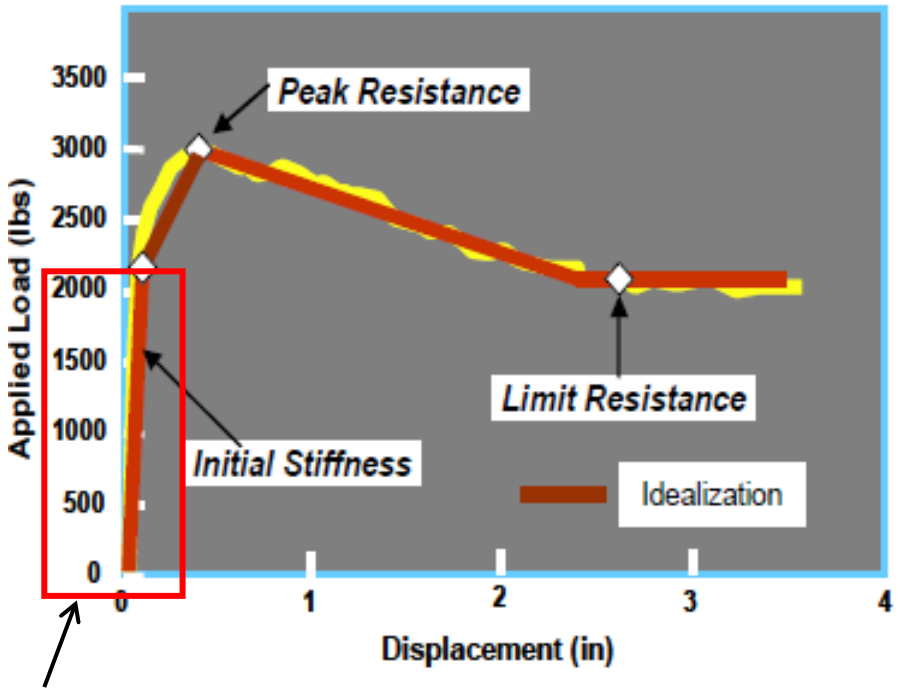
Jeniffer Barreto, José Varandas

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

1. Introduction
2. Methods
3. Results
4. Conclusions
5. Further developments

Stiffness and lateral resistance of the track

Fig. 1- Lateral behaviour of the track. Kish (2011)



area under study

2. Methods

Pegasus

Developed by Varandas (2013)

- Matlab program
- Linear (Hook's Law) and non-linear (K-θ) ballast behaviour
- Non-linear contact betwen the sleepers and the ballast (Penalty formulation)

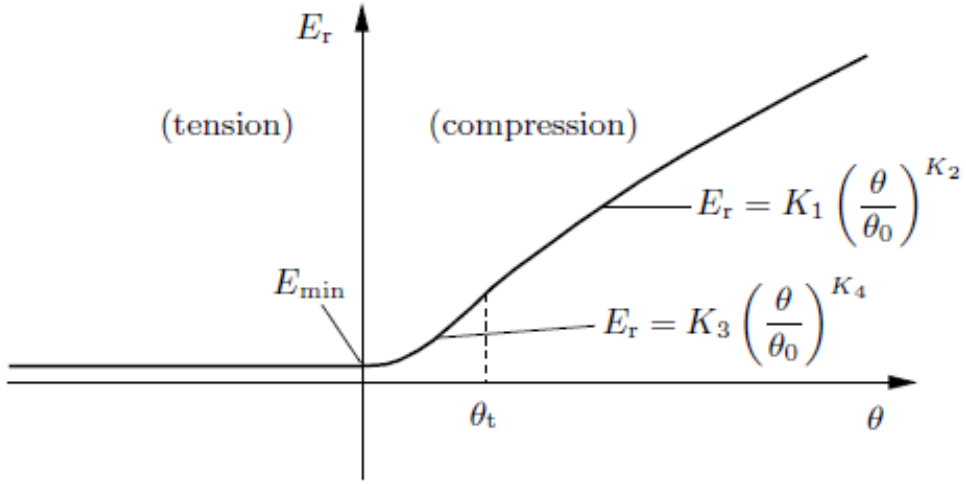


Fig.2 - The E_r-θ relationship . From Varandas (2013)

2. Methods

Model

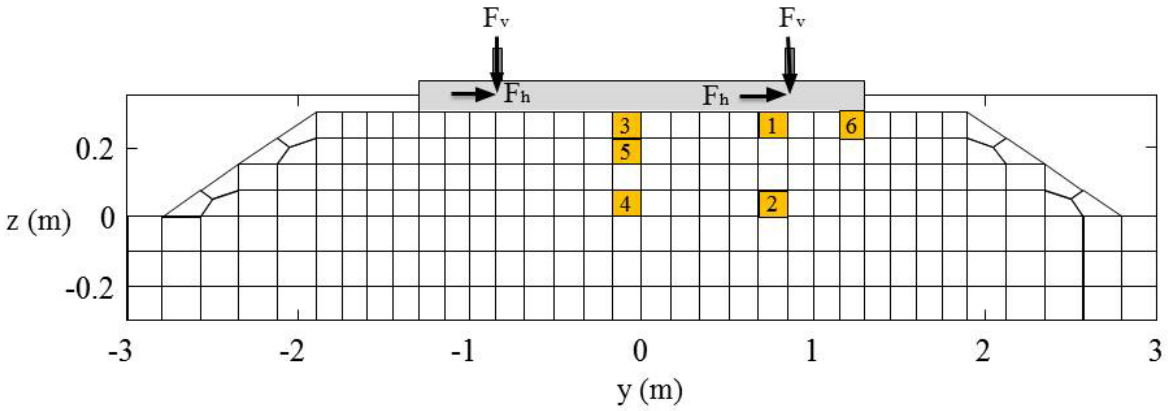


Fig.3 - Elemets in study

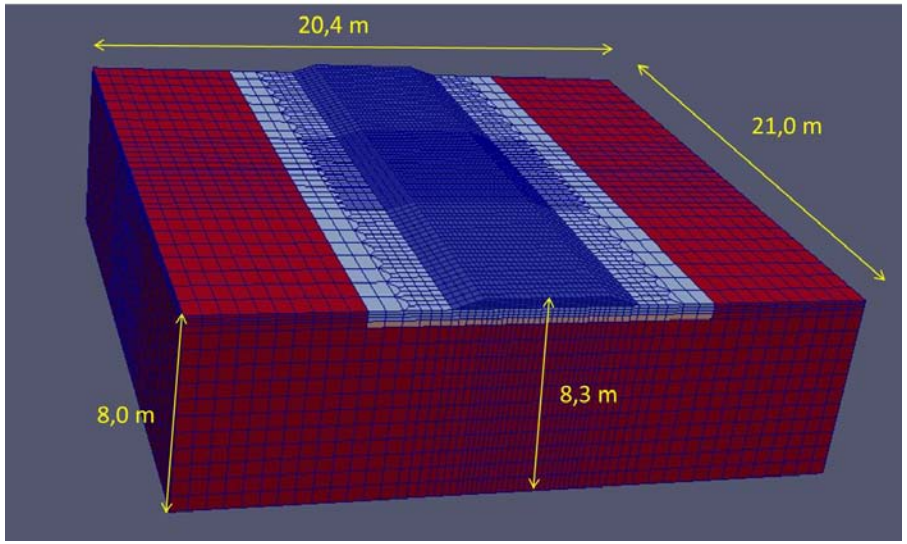


Fig.4- Geometry

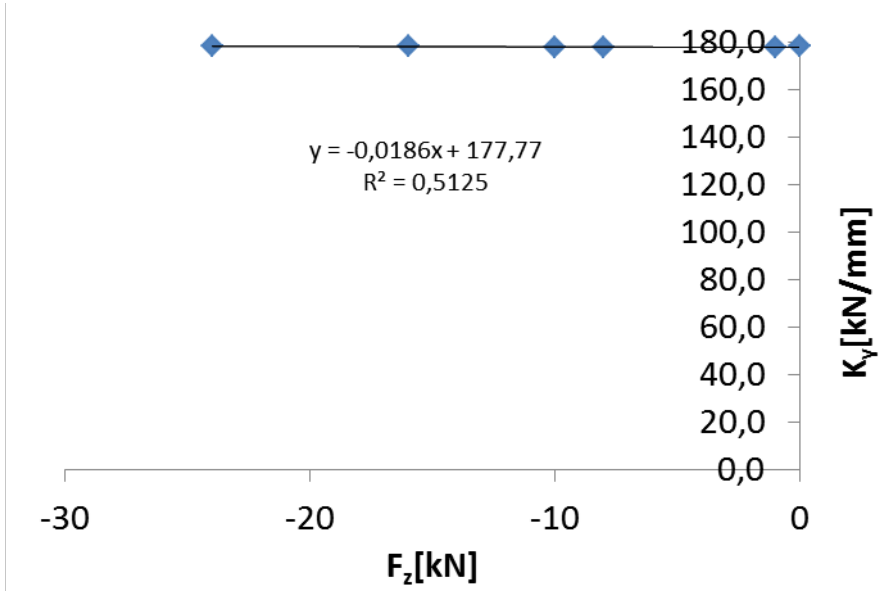
Vertical Load influence

Test	Soil layer 1 : E[mPa] -ν- ρ[t/m^3]	Soil foundation : E[mPa] - ν - ρ[t/m^3]	F_z [kN]	F_y [kN]	F_y/F_z	K_y [kN/mm]		K_z [kN/mm]	
						Non Linear	Linear	Non Linear	Linear
D1	200 - 0,35 - 1,8	150 - 0,35 - 1,8	1	8	8,00	68,9	-	68,1	-
D2	200 - 0,35 - 1,8	150 - 0,35 - 1,8	0	8	inf	71,4	178,1	0,0	0,0
D3	200 - 0,35 - 1,8	150 - 0,35 - 1,8	-1	8	8,00	74,0	177,6	144,7	222,6
D4	200 - 0,35 - 1,8	150 - 0,35 - 1,8	-8	8	1,00	89,8	177,8	110,3	264,0
D5	200 - 0,35 - 1,8	150 - 0,35 - 1,8	-10	8	0,80	93,5	177,9	111,4	265,4
D6	200 - 0,35 - 1,8	150 - 0,35 - 1,8	-16	8	0,50	103,1	178,1	114,8	267,5
D7	200 - 0,35 - 1,8	150 - 0,35 - 1,8	-24	8	0,33	103,1	178,3	119,1	268,7
D8	200 - 0,35 - 1,8	150 - 0,35 - 1,8	-40	8	0,20	129,1	-	125,7	-
D10	200 - 0,35 - 1,8	150 - 0,35 - 1,8	-60	8	0,13	143,8	-	131,7	-
D11	200 - 0,35 - 1,8	150 - 0,35 - 1,8	-75	8	0,11	152,8	-	135,2	-
D12	200 - 0,35 - 1,8	150 - 0,35 - 1,8	-100	8	0,08	165,5	-	140,0	-

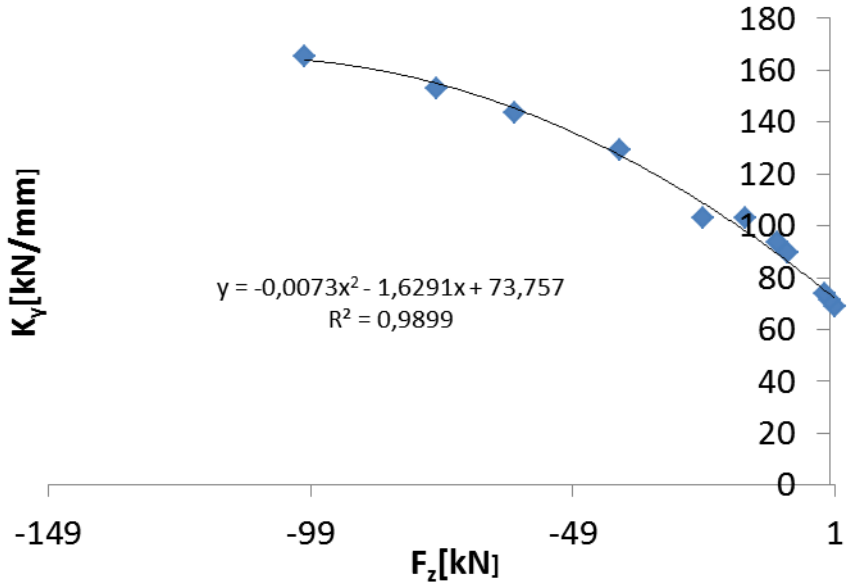
3. Results

Vertical Load influence – Stifiness : $K_i=2F_i/(u_{i,end}-u_{i,initial})$

Linear

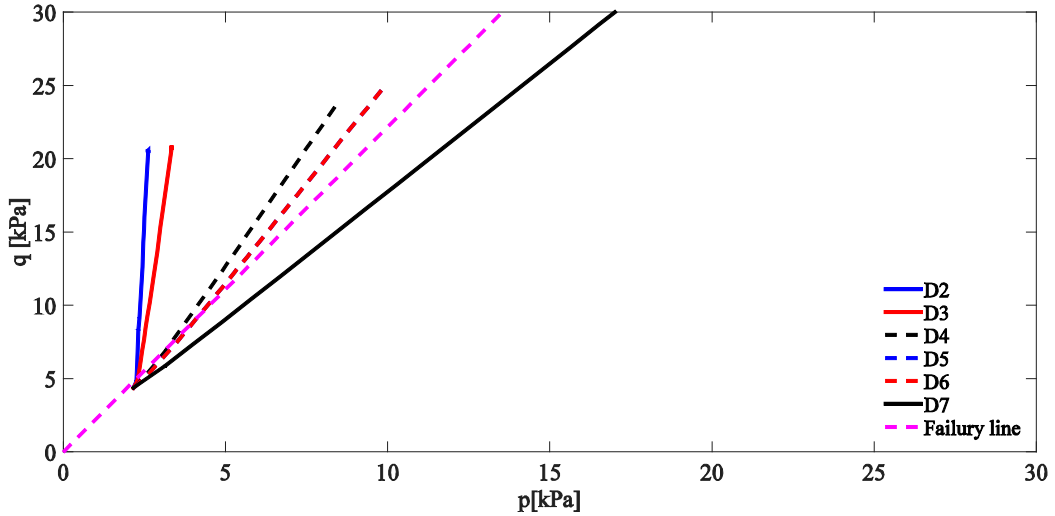


Nonlinear

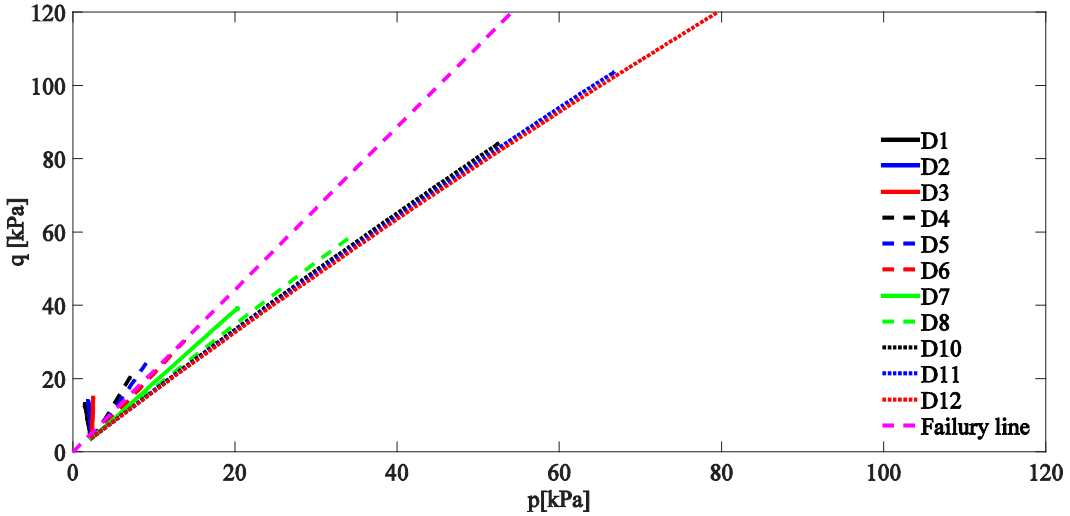


Vertical Load influence : p-q

Linear



Nonlinear



3. Results

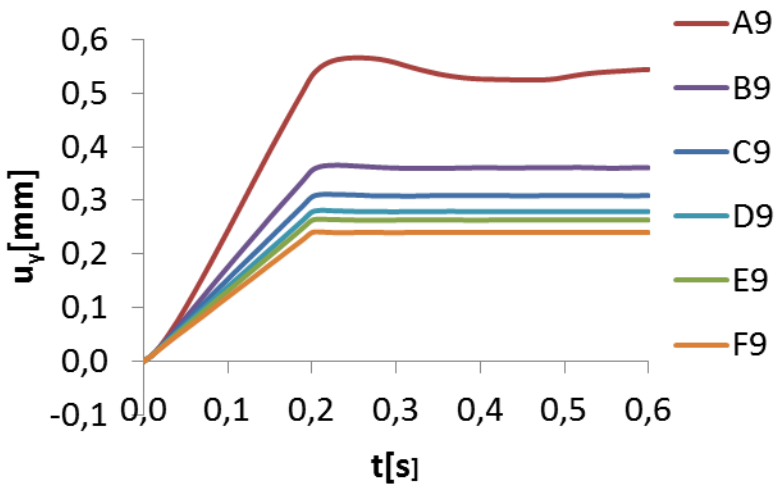
Soil Foudation influence

Test	Soil layer 1: E[mPa] - ν - ρ[t/m^3]	Soil foundation : E[mPa] - ν - ρ[t/m^3]	F_z [kN]	F_y [kN]	K_y [kN/mm]		K_z [kN/mm]	
					Non Linear	Linear	Non Linear	Linear
A9	200 - 0,35 - 1,8	20 -0,45- 2	-75	25	83,6	161,7	110,2	227,2
B9	200 - 0,35 - 1,8	60 - 0,3 - 2	-75	25	121,9	91,8	169,0	105,4
C9	200 - 0,35 - 1,8	100 - 0,3 -1,68	-75	25	140,1	189,7	232,8	292,8
D9	200 - 0,35 - 1,8	150-0,35-1,8	-75	25	152,0	208,2	269,5	341,9
E9	200 - 0,35 - 1,8	200 - 0,35 - 2	-75	25	159,6	138,5	301,4	164,7
F9	200 - 0,35 - 1,8	300-0,3-2,04	-75	25	169,7	178,9	338,2	265,9

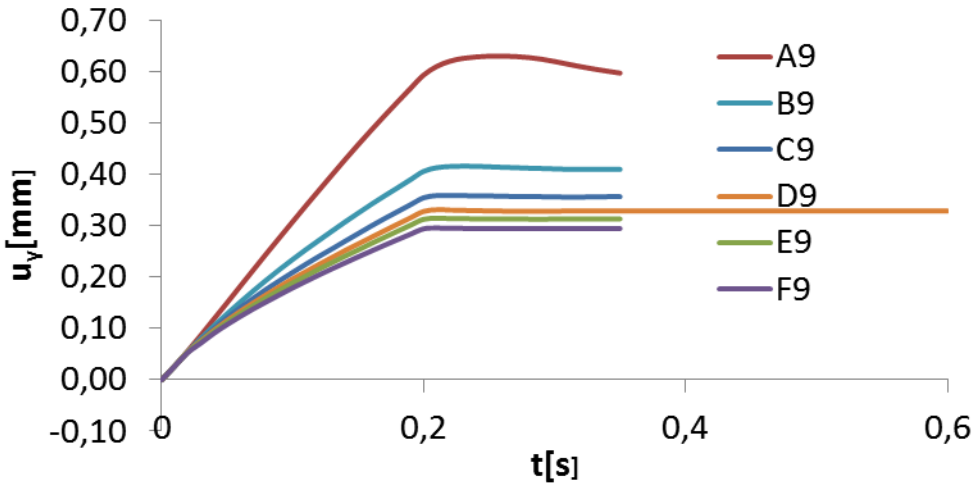
3. Results

Soil Foudation influence : u_y

Linear



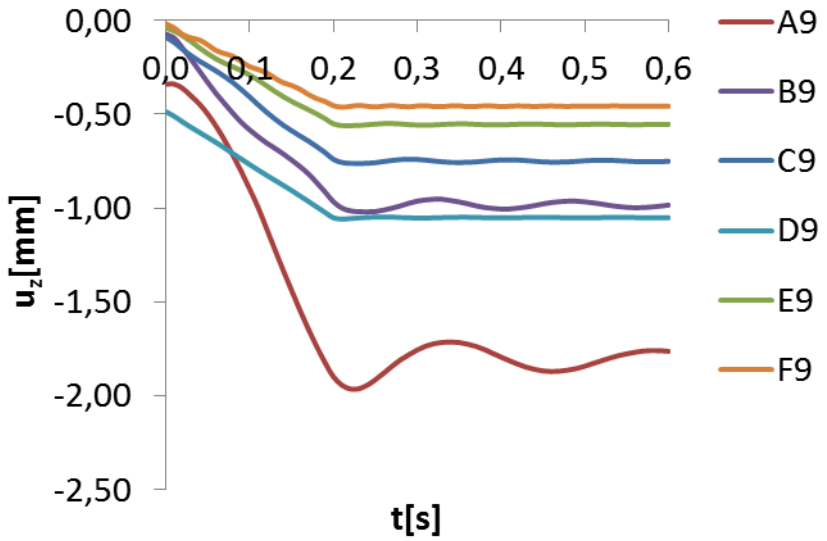
Nonlinear



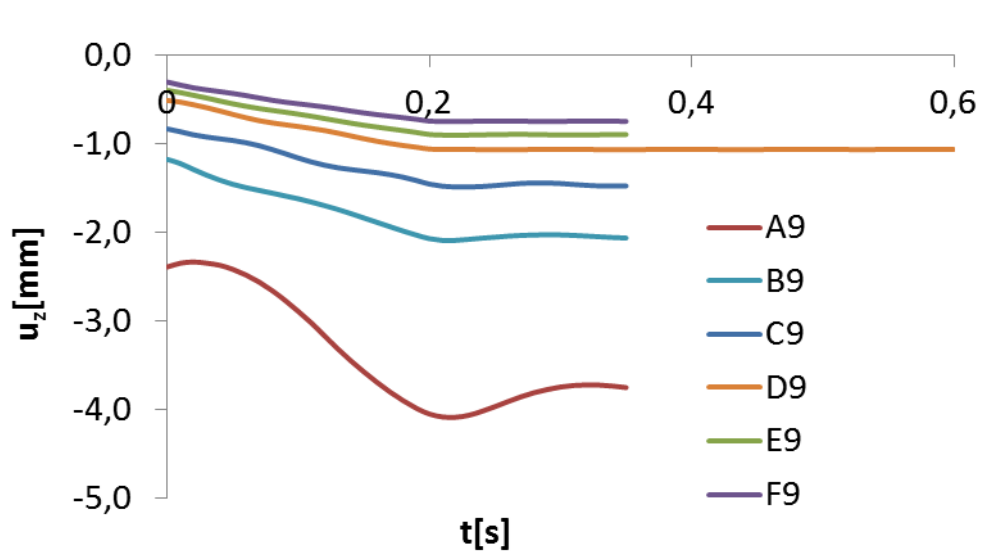
3. Results

Soil Foudation influence : u_z

Linear



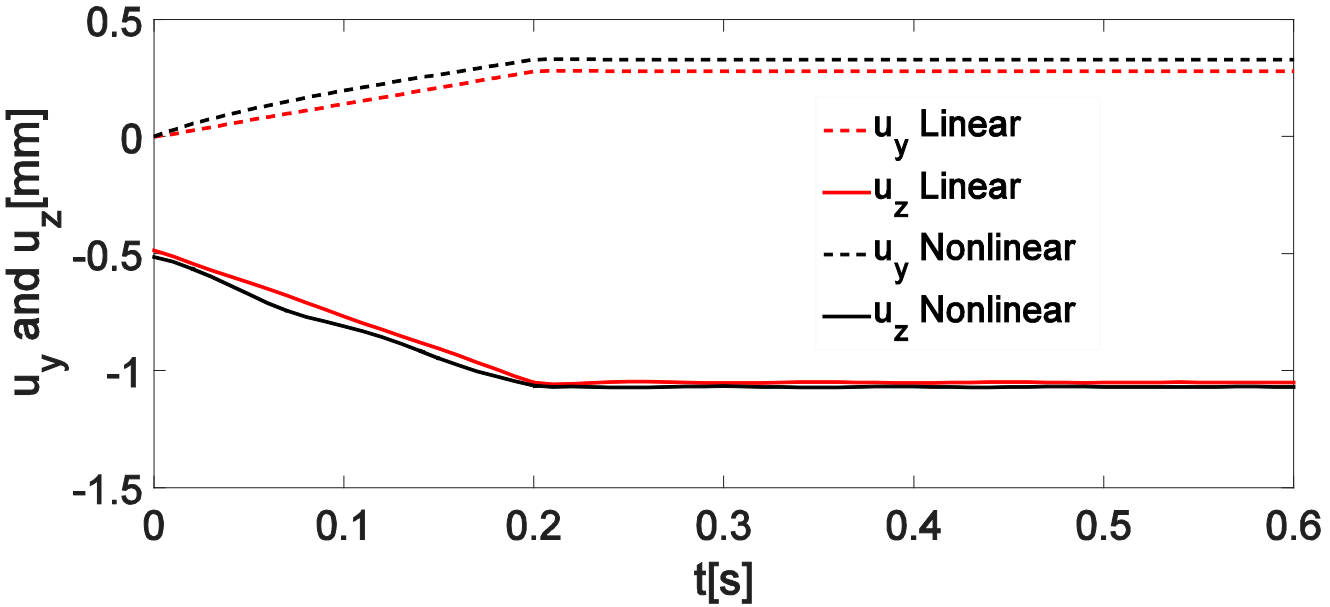
Nonlinear



3. Results

Test D9 – comparison between the linear model and the nonlinear

Displacements

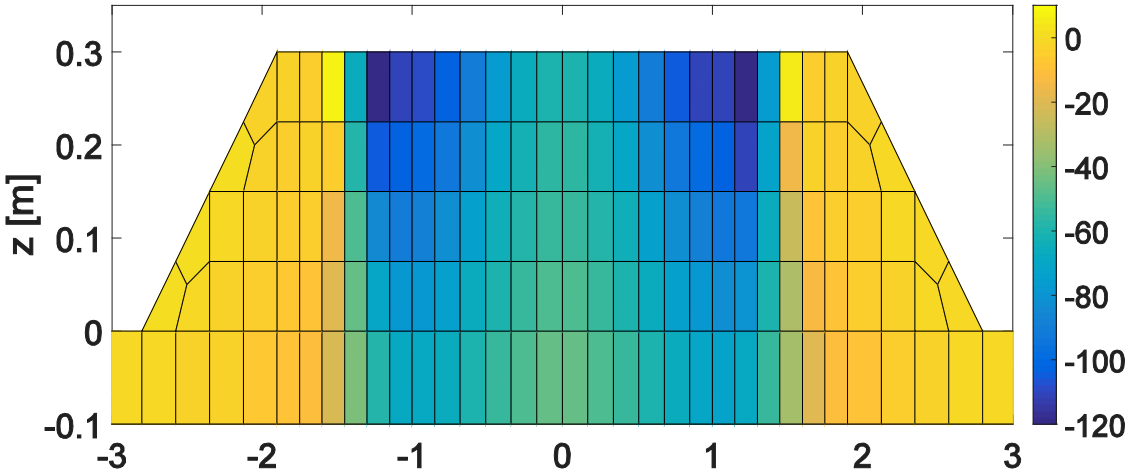


3. Results

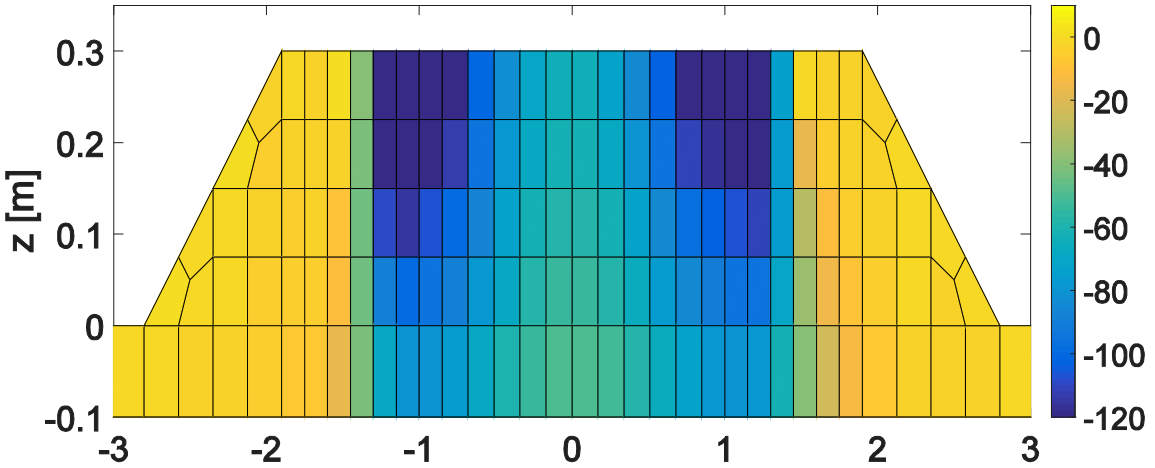
Test D9 – comparison between the linear model and the nonlinear

Stress

σ_z Linear



σ_z Nonlinear



3. Results

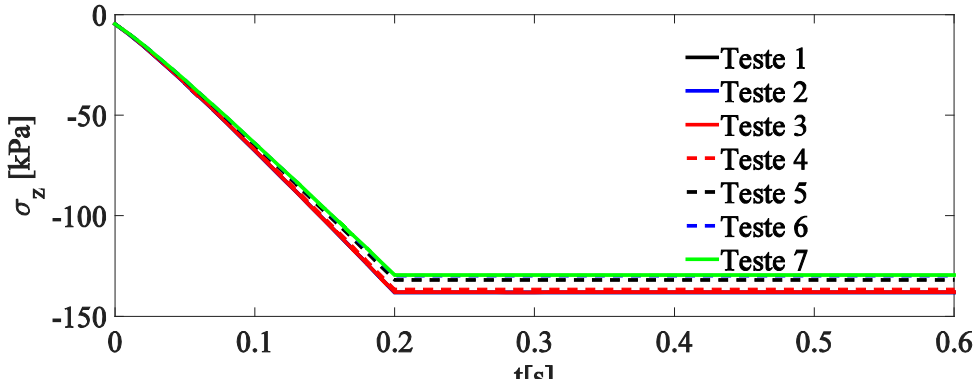
Influence of the lateral sleeper-ballast interaction , $K_{c,h}$ on the stress distribution in the ballast

	Test 1	Test 2	Test 3	Test 4	Test 5	Test 6	Test 7
$K_{c,h}[kN/m^2]$	0	$1x10^2$	$1x10^4$	$1x10^5$	$1x10^6$	$5x10^6$	$1x10^7$
$F_z[kN]$	-75	-75	-75	-75	-75	-75	-75
$F_y[kN]$	0	0	0	0	0	0	0
Foudation soil	D	D	D	D	D	D	D

3. Results

Influence of the lateral sleeper-ballast interaction on the stress distribution in the ballast -σ_z

Elem 1



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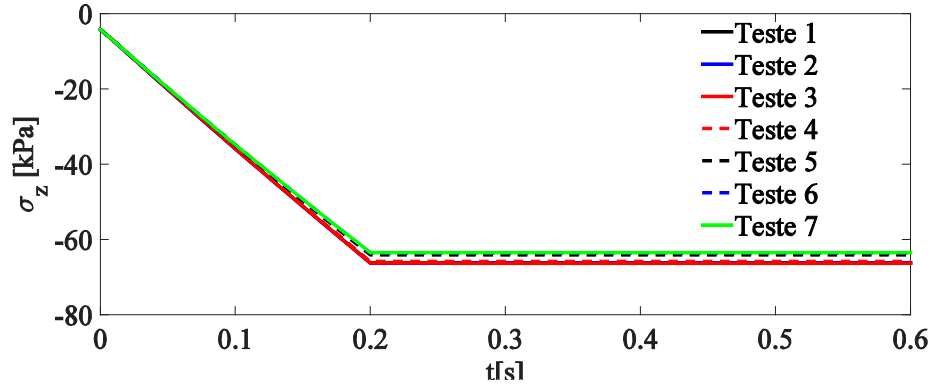

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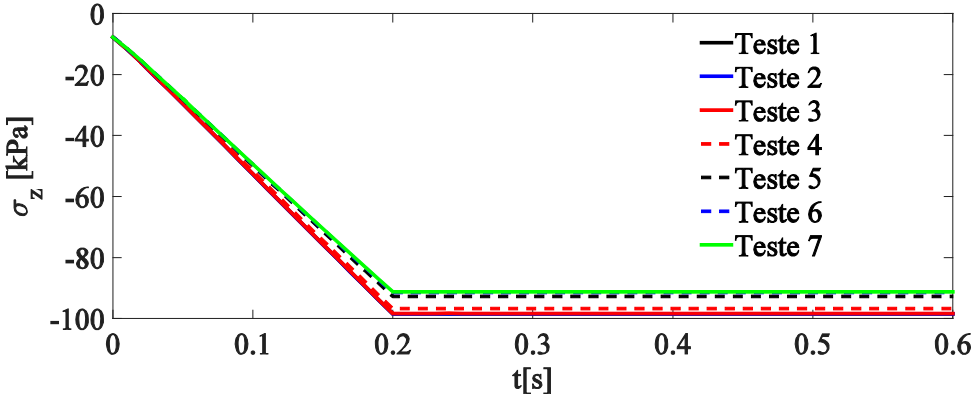

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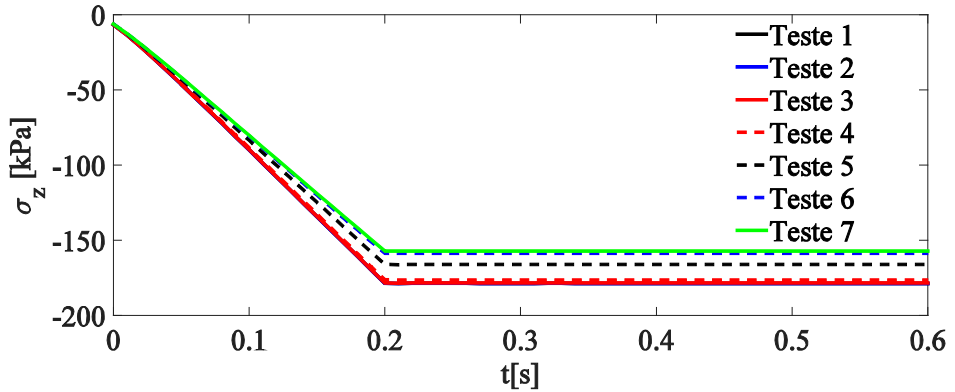
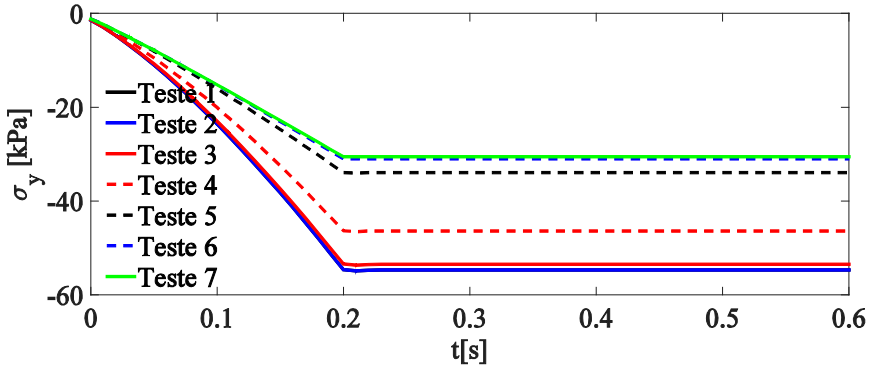


Influence of the lateral sleeper-ballast interaction on the stress distribution in the ballast -σ_y

Elem 1



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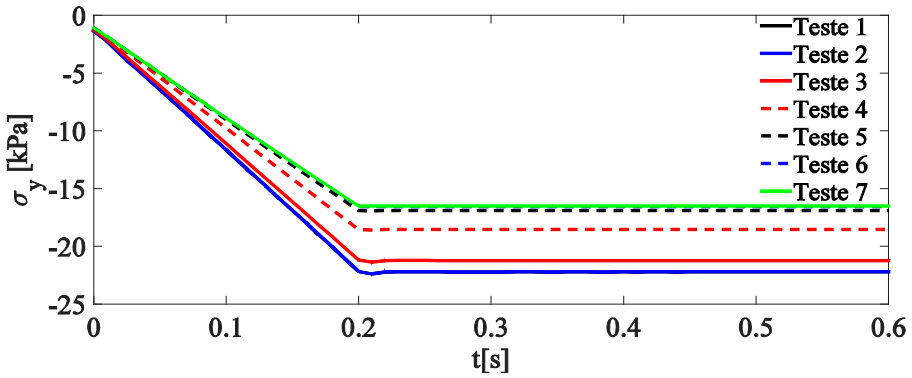

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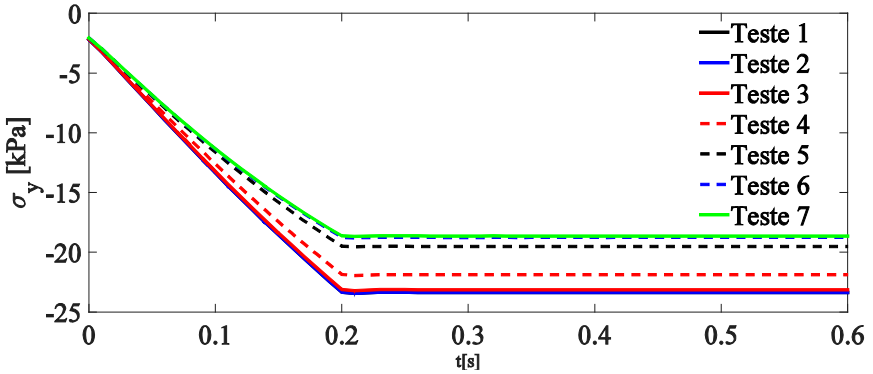

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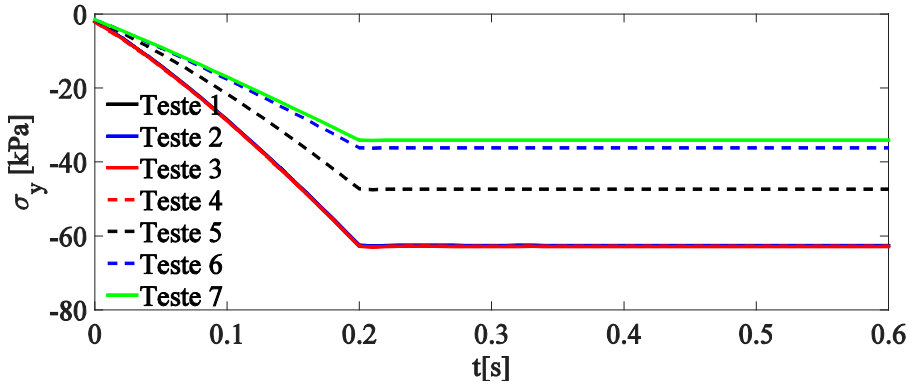

Conclusions

- Load study – It was possible to obtain vertical load (F_z) - lateral stiffness (K_y) relation. For higher F_y/F_z relation, the graph p-q lies above the failure line .
- Soil foundation study – As expected, it was observed that the higher the Young modulus of the soil the higher the lateral stiffness .
- Influence of the lateral sleeper-ballast interaction on the stress distribution in the ballast – It is noted that the parameter $K_{c,h}$ has a non negligible influence on the stresse distribution inside the ballast layer, therefore denoting the importance of a care representation of this friction interface in studies focused on the granular layers of the track .

Thank you for your attention

Universidade Nova de Lisboa-Faculdade de Ciências e Tecnologias, Lisboa, Portugal
Jeniffer costa Barreto - *jc.barreto@campus.fct.unl.pt*
José Varandas - *jnsf@fct.unl.pt*