C4R

Capacity for Rail

Innovative designs and methods for VHST

2nd Dissemination Event, Brussels –3rd November 2016

Miguel Rodríguez Plaza
Adif

SEVENTH FRAMEWORK PROGRAMME

Introduction

- C4R WP 1.2: VHST
  - Objectives:
    - To identify market requirements, technical barriers and future ways of operating the VHST.
    - To analyse and study the impact in VHST specific questions in terms of severity of dynamic solicitations for structural design and new innovation for transition zones.
    - To identify bridge design requirements for VHST.
    - To evaluate theoretical findings in a track box at 350 - 400 kph.
- New concepts for new VHSL including freight operation at HS.
- New track design and specifications for VHST (over 350 kph)
    - Track design for VHST, transition zones, damping considerations and track irregularities (CEDEX)
    - Verification by full scale tests (CEDEX)
- Structures dynamical effects due to very high speed
    - Calculation methods and models. (SYSTRA)
    - Verification of 2.3.1 by full scale tests. (KTH)

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- **Task 1.2.2 New track design and specifications for VHST**
  - Sub-Task 1.2.2.1 Track design for VHST (IST)
    - Track design solution for rail pads and under sleeper pads.
    - Parametric study on train speed increase.
- **Task 1.2.3 Structures dynamical effects due to very high speed**
  - Sub-Task 1.2.3.2 Verification of Calculation methods and models by full scale tests. (Adif, CEDEX, INECO)
    - Track test at a frame with trains passing at a max speed of 358 km/h
  - Sub-Task 1.2.3.1 Calculation methods and models. (SYSTRA)
    - Deck and rolling stock acceleration function of train speed.

C4R SP1 WP1.2

Task 1.2.2 New track design and specifications for VHST

Sub-Task 1.2.2.1 Track design for VHST

Track design solution for rail pads and under sleeper pads.

Parametric study on train speed increase.

P. Ferreira, R. Maciel

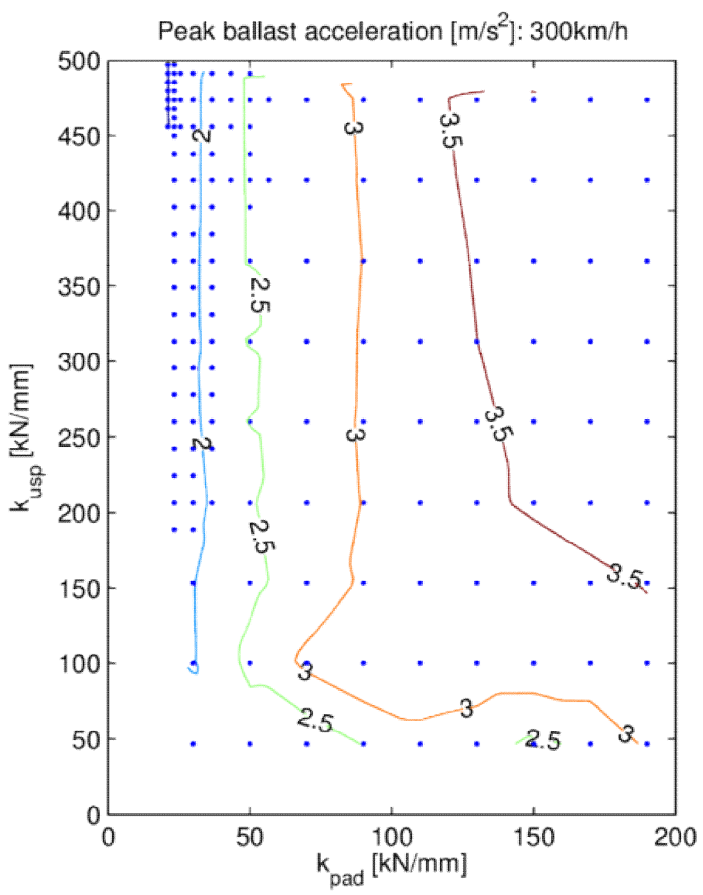
Sub-Task 1.2.2.1 Track design for VHST

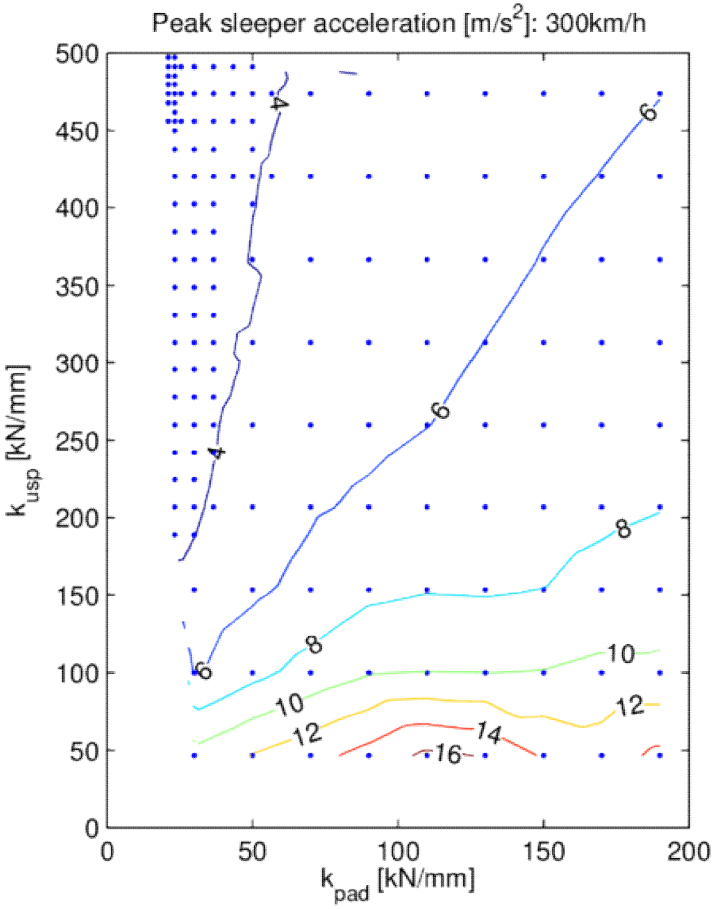
IST, ADIF and CEDEX have been working in a parametric study to evaluate the predicted dynamic response of the reference railway track when equipped with specific combinations of railpads and under-sleeper pads (USPs).

The numerical model used for the simulations was previously validated based on the data provided by CEDEX from the tests conducted on the physical model of a ballasted track with granular subballast.

Hence, the short term response of the test track, represented by experimental measurements collected on the Track Box test track, were used as benchmark results.

Track response overview: 300km/h





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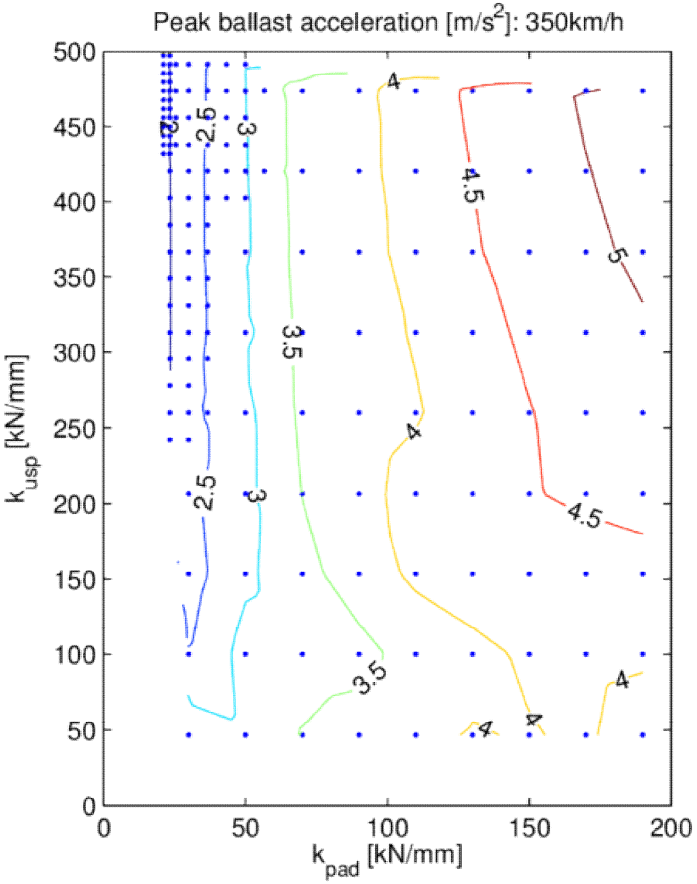
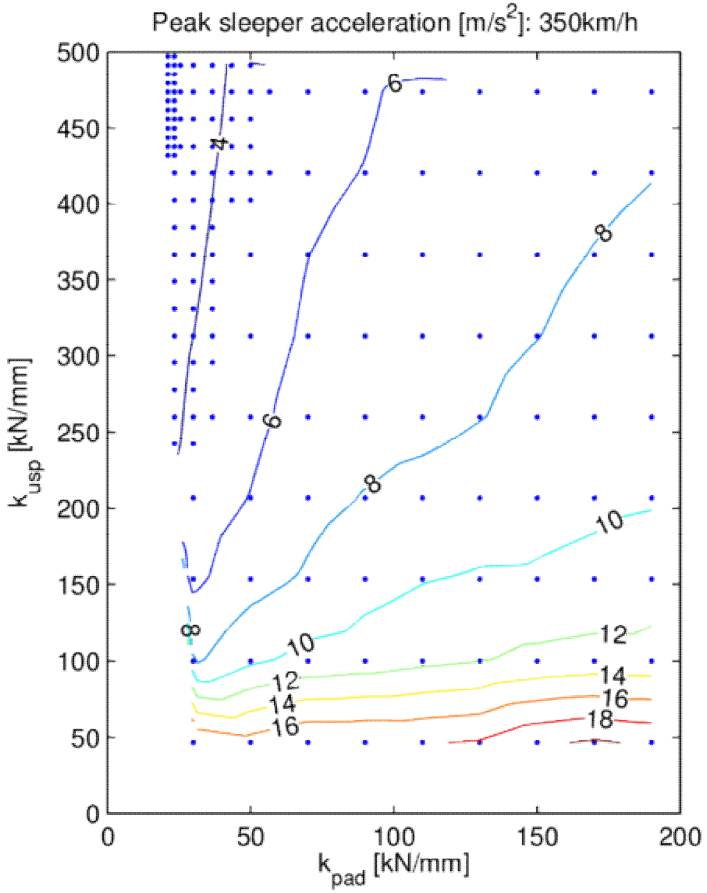
Track response overview: 350km/h





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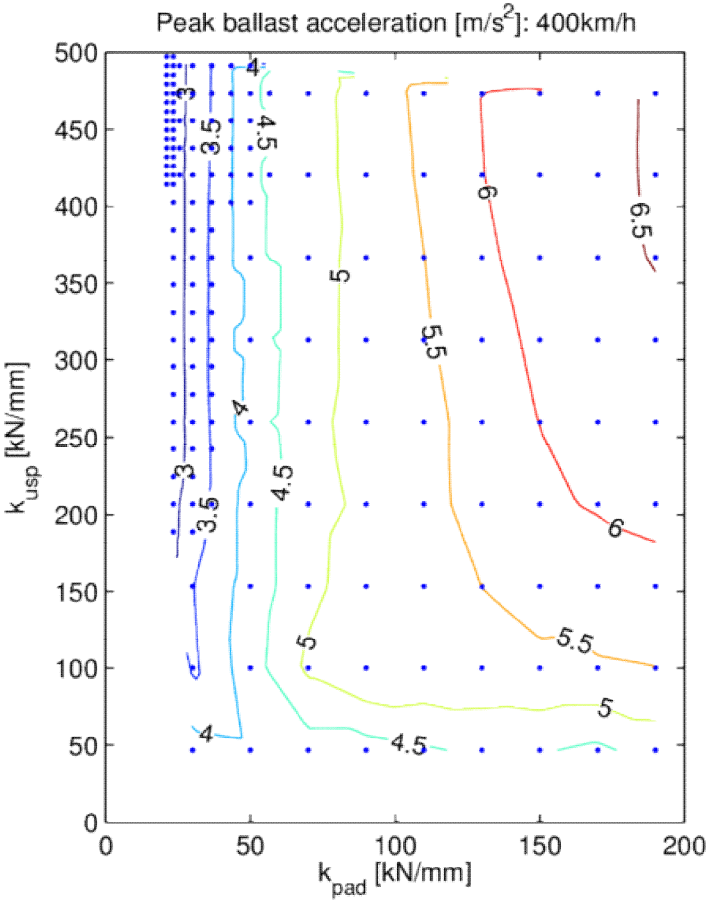
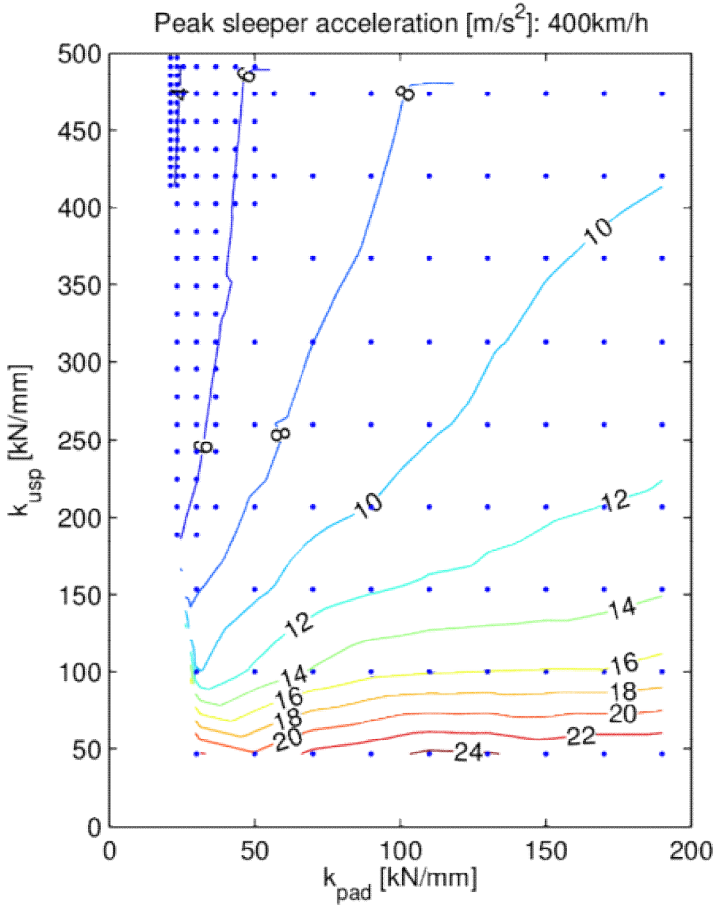
Track response overview: 400km/h





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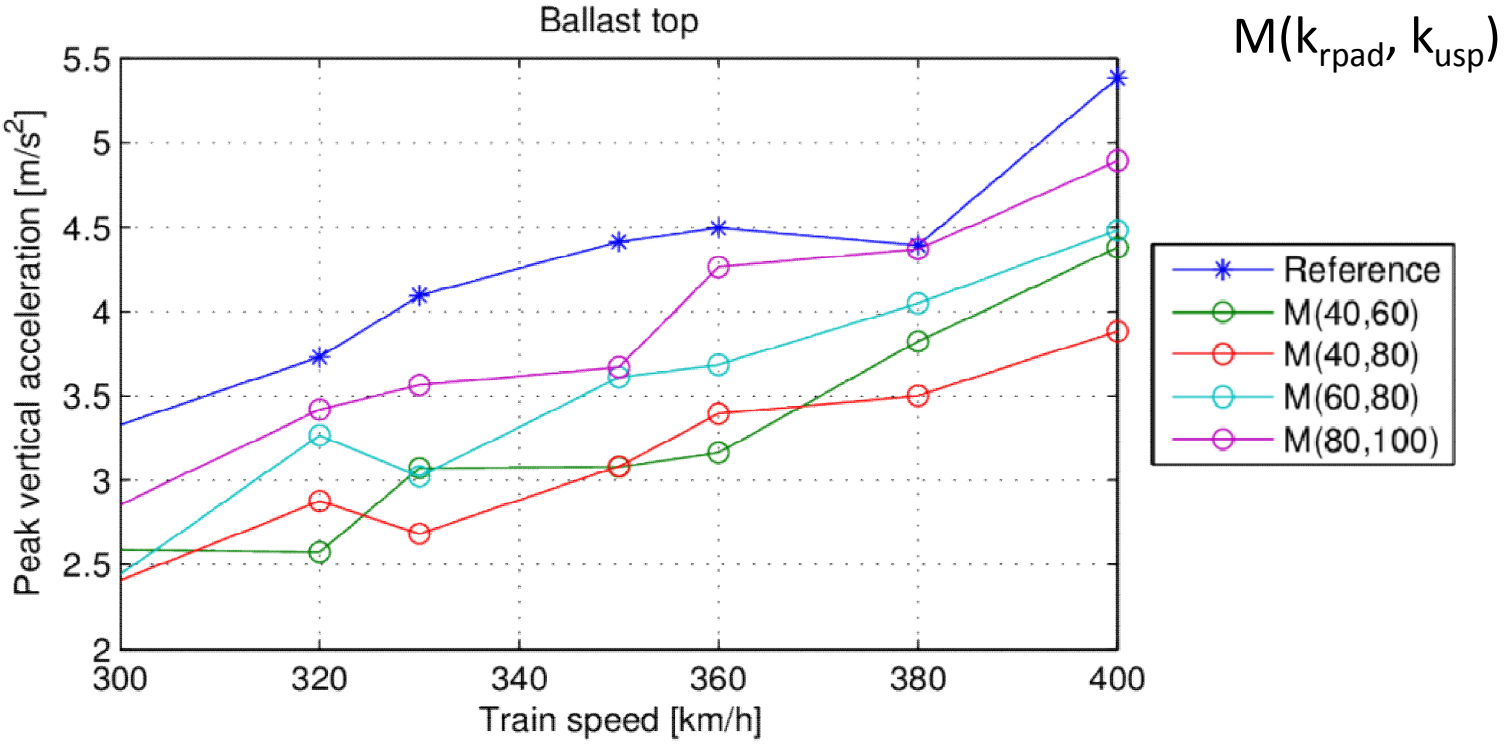
Track response overview: key aspects

- Peak sleeper acceleration
  - Decrease with increased kusp
  - Sensitivity is higher when kusp is low
  - Peak values are very high when kusp is low
  - Qualitatively, the link between peak vertical stiffness levels and the design parameters (vertical stiffness of rail pads and USPs) is observed on all circulation speeds.
- Peak ballast acceleration
  - Insensitive to k_{usp}, except when kusp values are very low
  - Sensitive to k_{pad}
- Caution
  - No data on USP tracks
  - No measurements from VHS trains at 400km/h

Parametric study (soft USP)

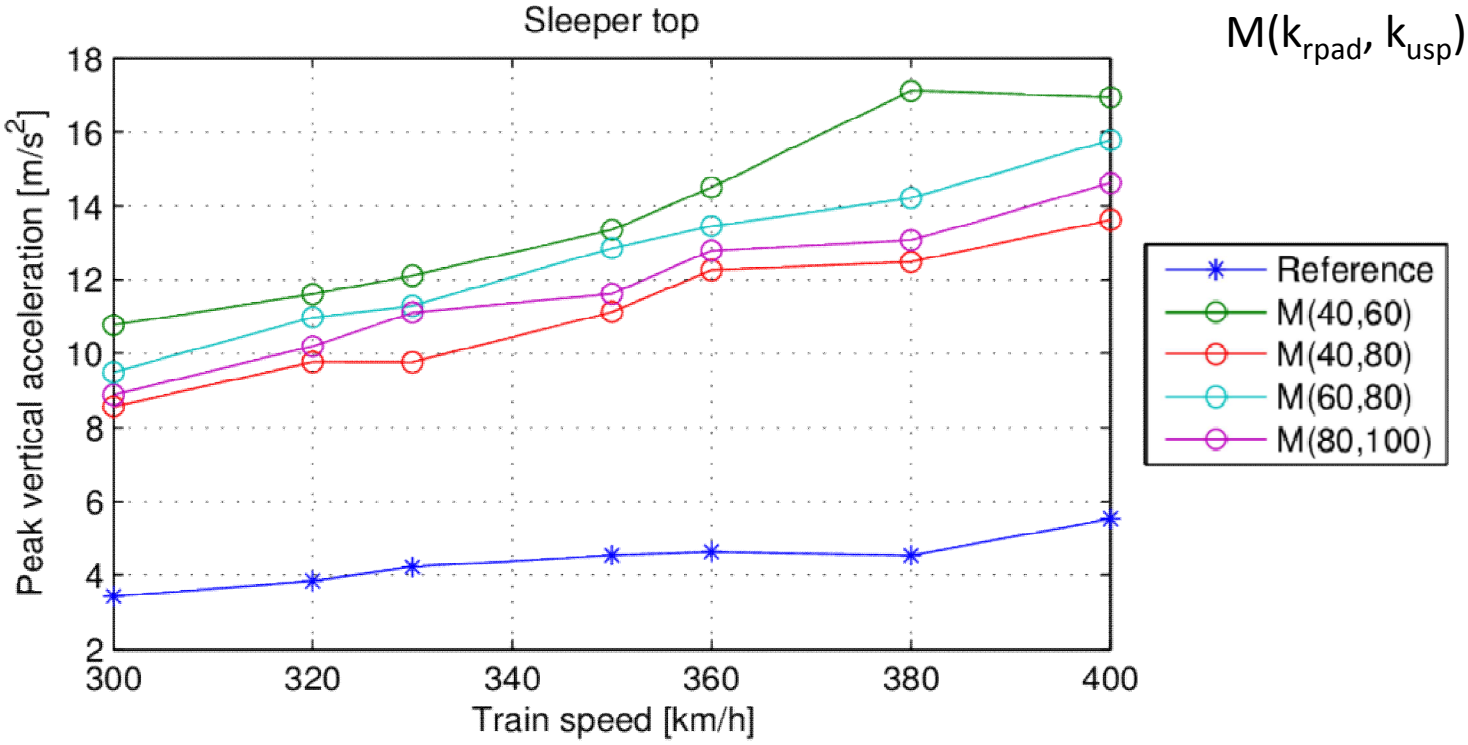
Influence of train speed



$M(k_{rpad}, k_{usp})$

Parametric study (soft USP)

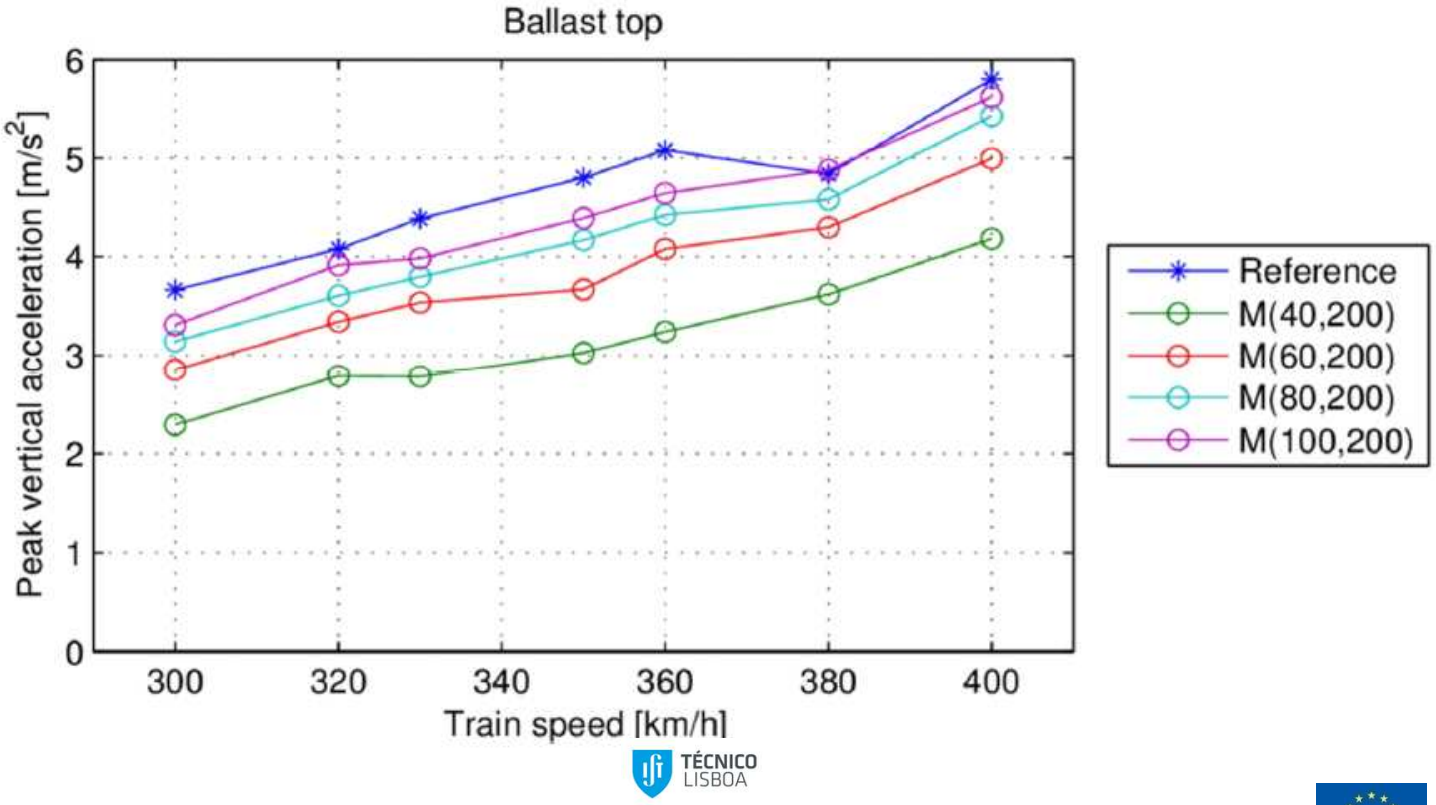
Influence of train speed



Parametric study (stiff USP)

Influence of train speed

$M(k_{rpad}, k_{usp})$



Parametric study (stiff USP)

Influence of train speed

$M(k_{rpad}, k_{usp})$

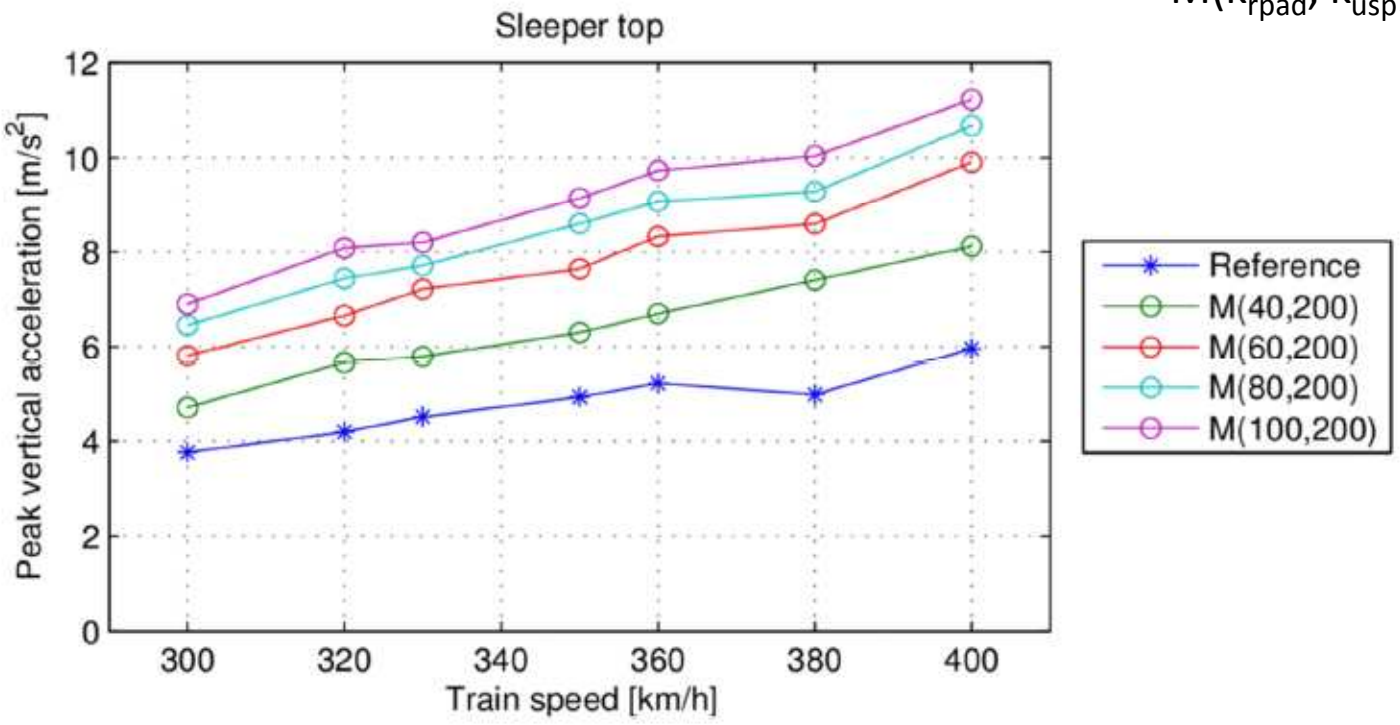


FIGURE 5.6 COMPARISON OF PEAK SLEEPER ACCELERATION VALUES WITH REGARDS TO TRAIN SPEED: K_{USP} 200 KN/MM.

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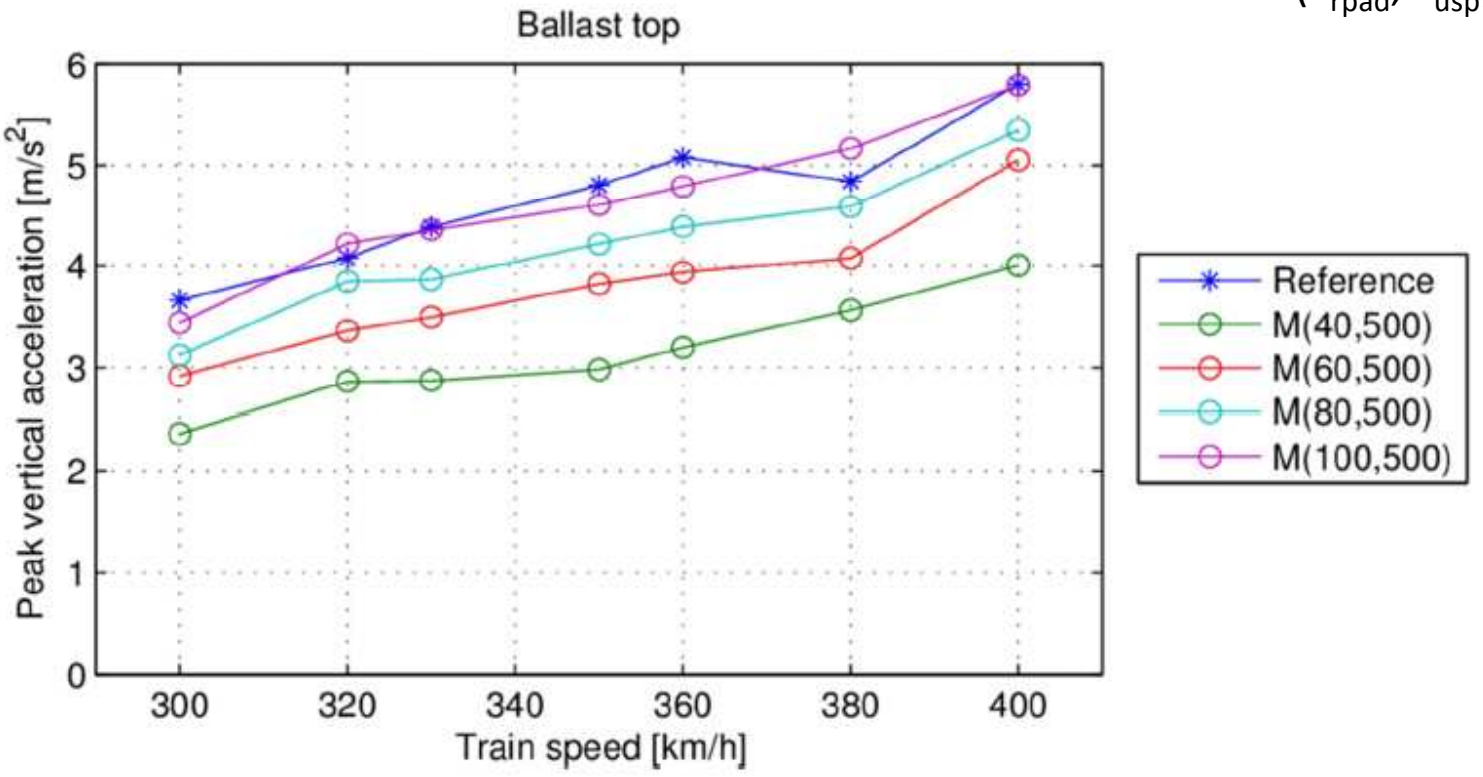
Parametric study (stiff USP)

Influence of train speed

$M(k_{rpad}, k_{usp})$



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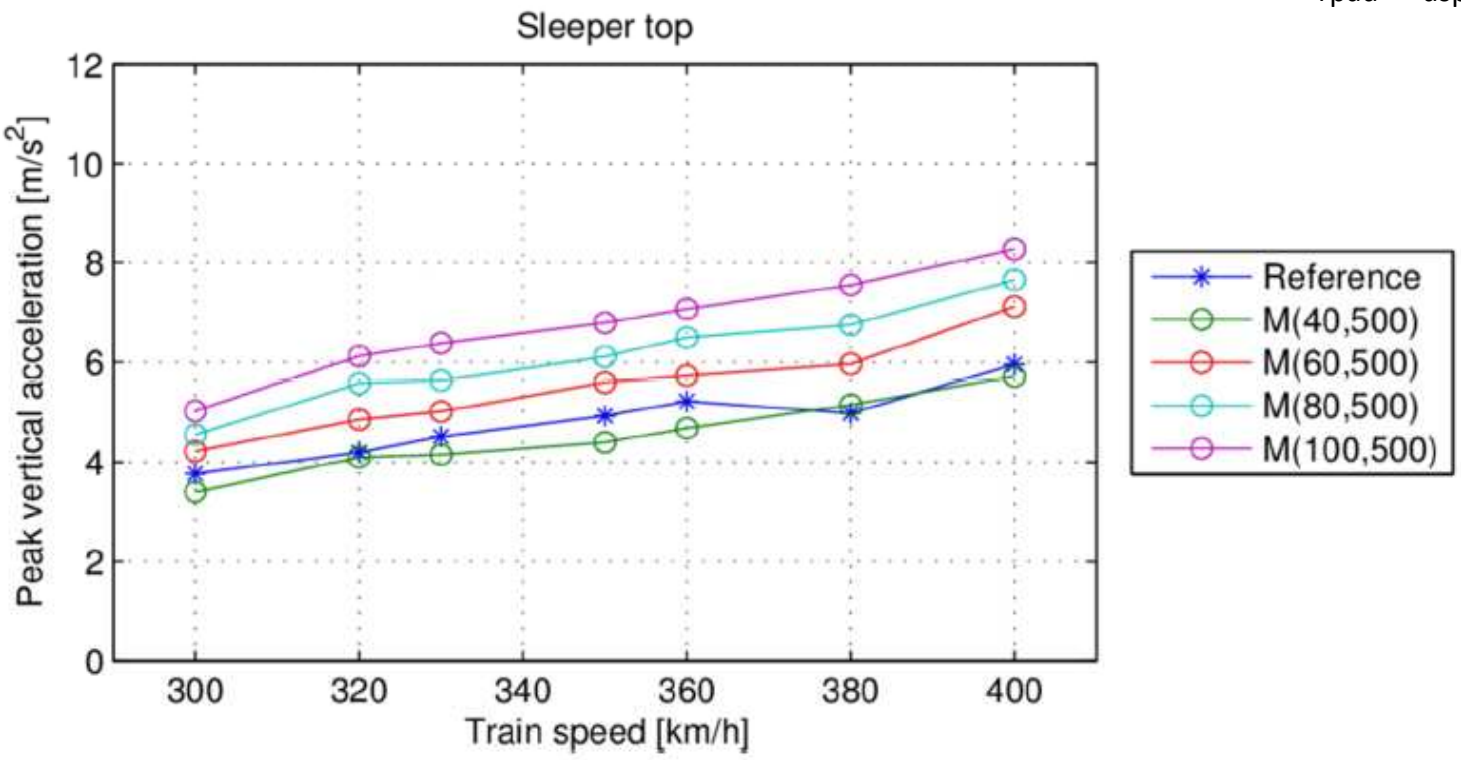
Parametric study (stiff USP)

Influence of train speed

$M(k_{rpad}, k_{usp})$



Test plan

To support experimental tests in CEDEX Track Box

TABLE 7.1 TEST PLAN TRACK VARIANTS.

M (K_{rpad}, K_{USP})

Test reference	Kpad [kN/mm]	Kusp [kN/mm]	Variant description	Notes
Test 1	100	-	M(100,-)	Track box Model 1
Test 2	40	-	M(40,-)	
Test 3	60	-	M(60,-)	
Test 4	40	80	M(40,80)	Test 2 + USP
Test 5	60	80	M(60,80)	Test 3 + USP
	80	80	M(80,80)	Additional variant
Test 1 + USP	100	80	M(100,80)	Reference + USP
	80	50	M(80,50)	Additional variant
	100	50	M(100,50)	Additional variant
	60	200	M(60,200)	Additional variant
	60	500	M(60,500)	Additional variant

The resulting full factorial design lead to a computer experiment requiring nearly 50 train-track simulation runs

Test plan

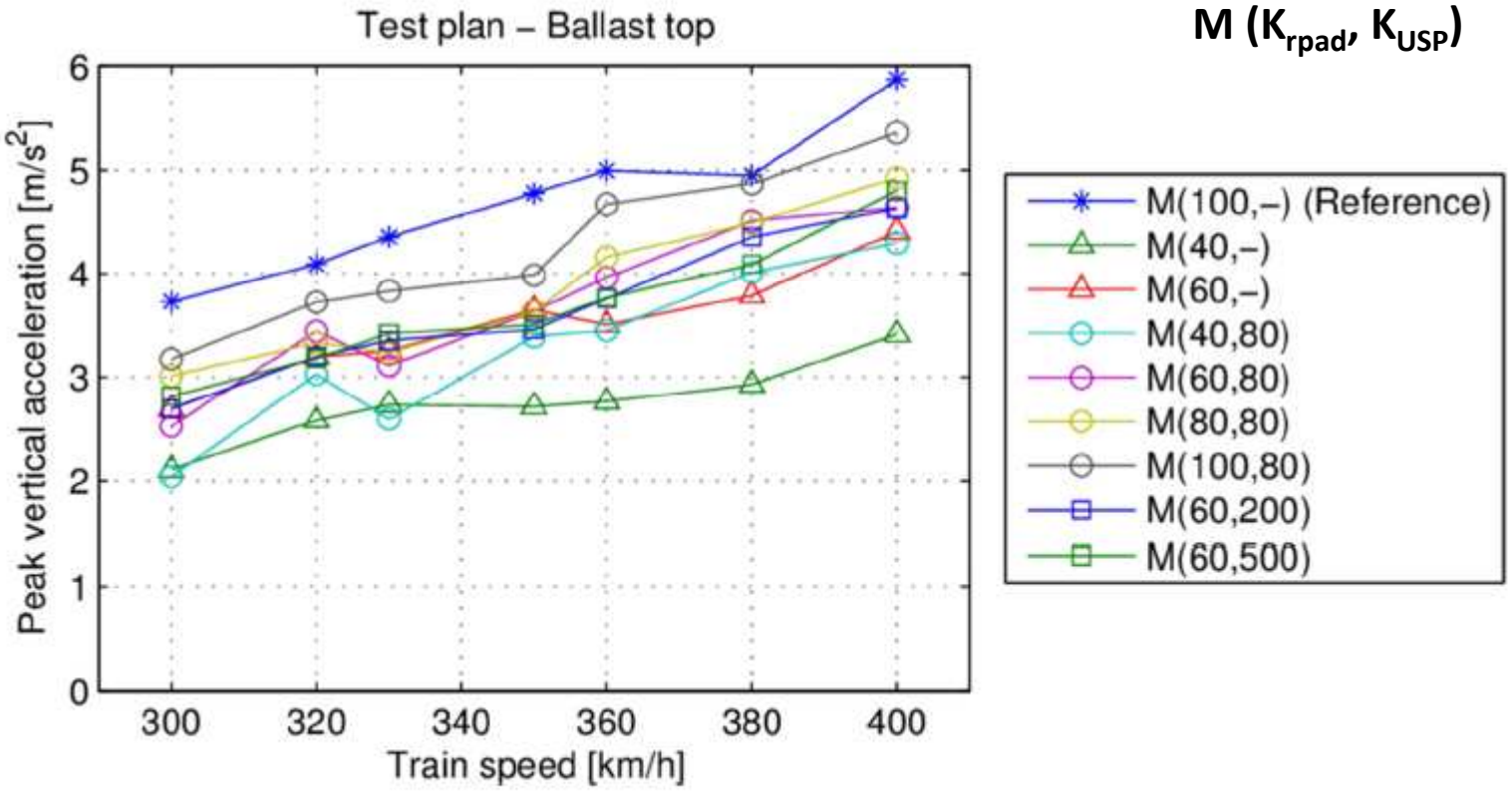


FIGURE 7.3 PEAK BALLAST ACCELERATION WITH REGARDS TO TRAIN CIRCULATION SPEED: STIFF USPS.

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Test plan

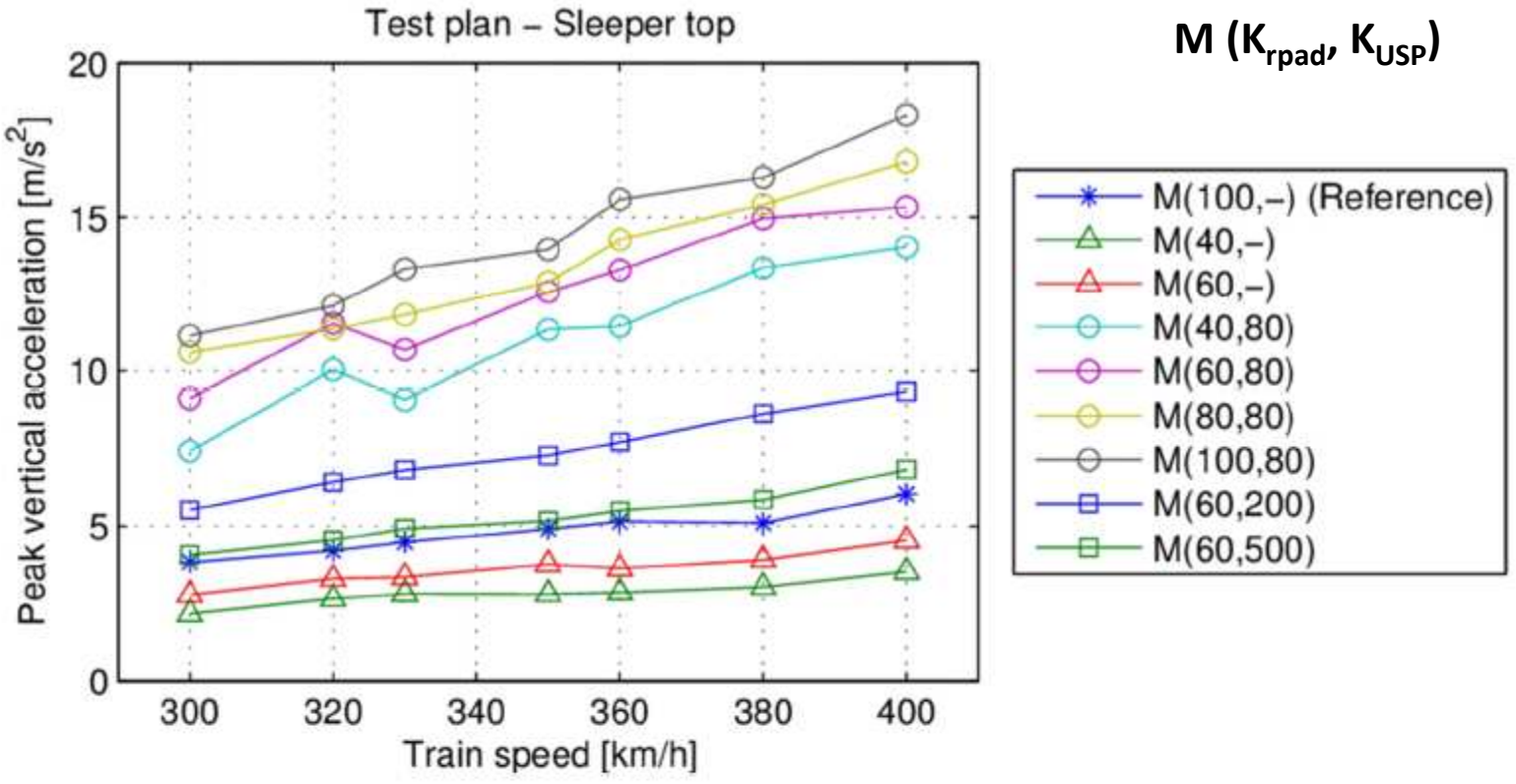

FIGURE 7.4 PEAK SLEEPER ACCELERATION WITH REGARDS TO TRAIN CIRCULATION SPEED: STIFF USPS.

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Test plan

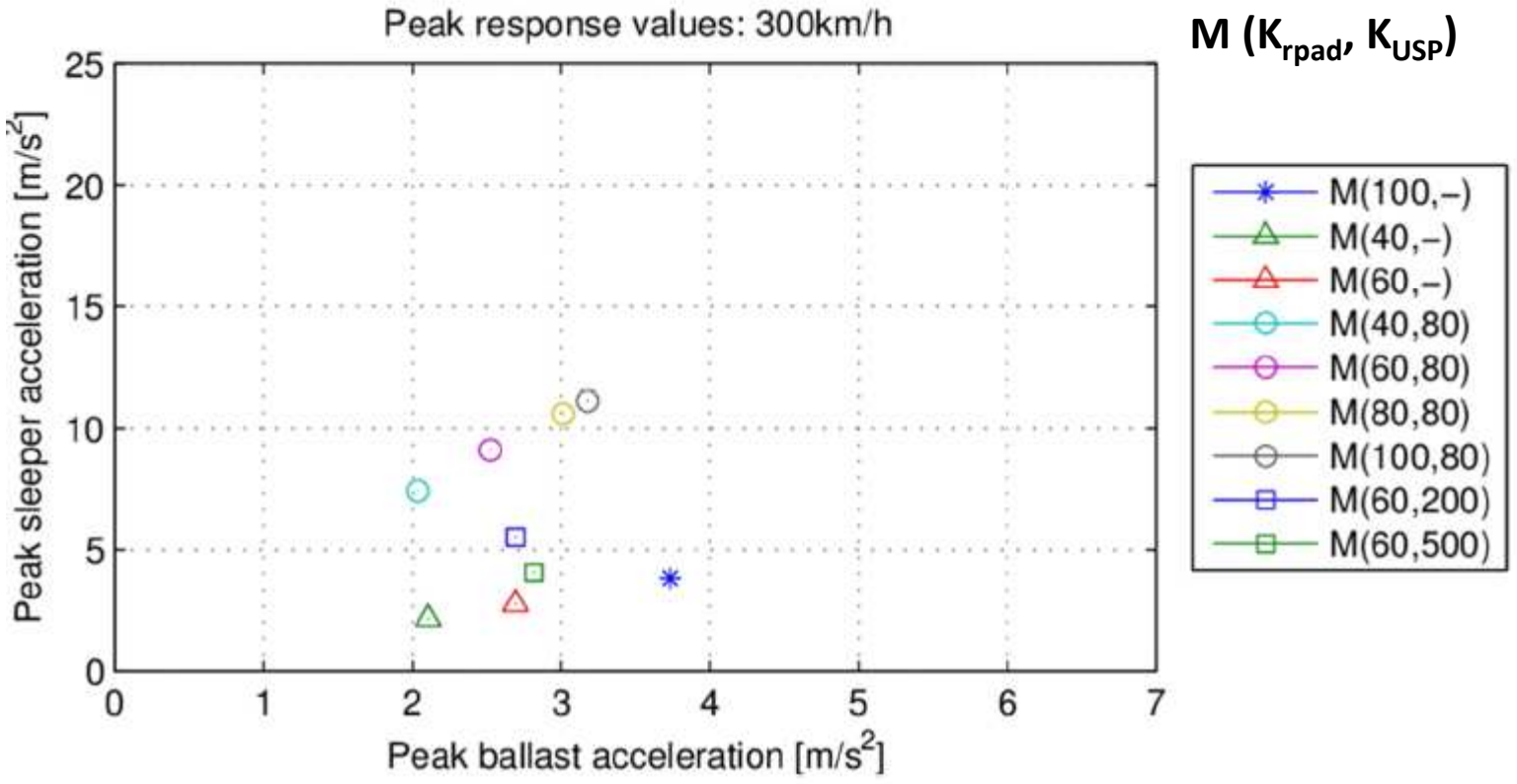

FIGURE 7.8 PEAK ACCELERATION RESPONSES: 300 KM/H.

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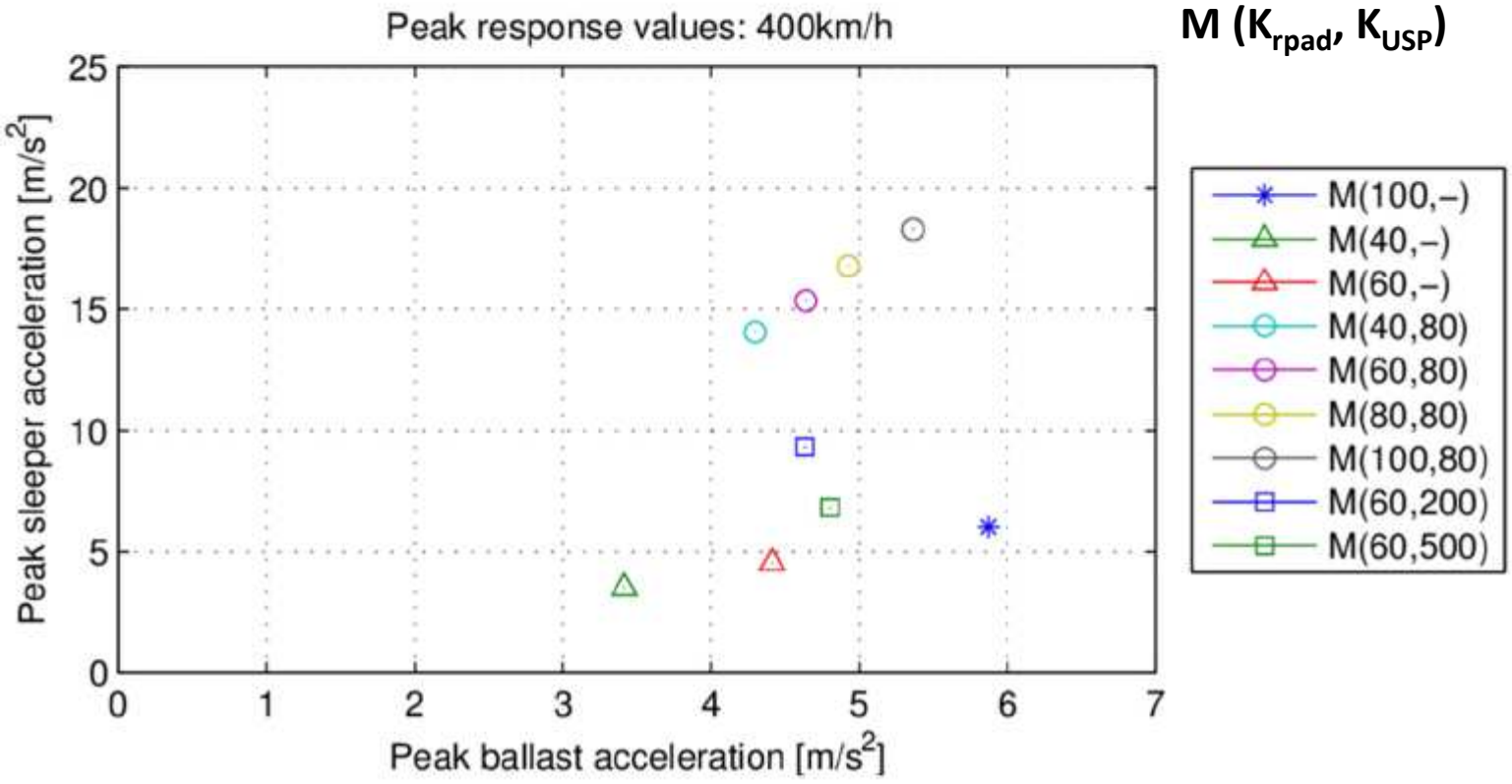

FIGURE 7.10 PEAK ACCELERATION RESPONSES: 400 KM/H.

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Remarks

- *The introduction of USPs results in a significant reduction in peak vertical displacement and acceleration levels within the track supporting layers, ballast layer included.*
- *However, it must be highlighted that these improvements are accompanied by increases in peak vertical displacement and acceleration levels on track components supported by the USPs, as the rails and the sleepers.*
- *Notwithstanding, the results also suggest that incorporating stiffer USPs may reduce peak acceleration levels within the ballast layer while preserving peak sleeper acceleration levels.*

Remarks

The interpretation and critical analysis of the results attention must be paid to the following:

- The numerical model is not able to consider the following positive effects (most possibly) provided by the USPs:
  - increase in the interface and load-distributing area between sleepers and ballast;
  - embedding effect of the ballast stones by the USP elastic layer;
- Any results obtained for trains speeds of 400km/h must be taken with care as no validation with real measurements was made at these speeds;
- The numerical results here analysed are provided exclusively from short term computations, that is, only track instantaneous responses are obtained, so, conclusions cannot be directly extrapolated to track long-term performance nor within a life cycle analysis perspective;

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Task 1.2.3 Structures dynamical effects due to very high speed

Sub-Task 1.2.3.2 Verification of Calculation methods and models by full scale tests.

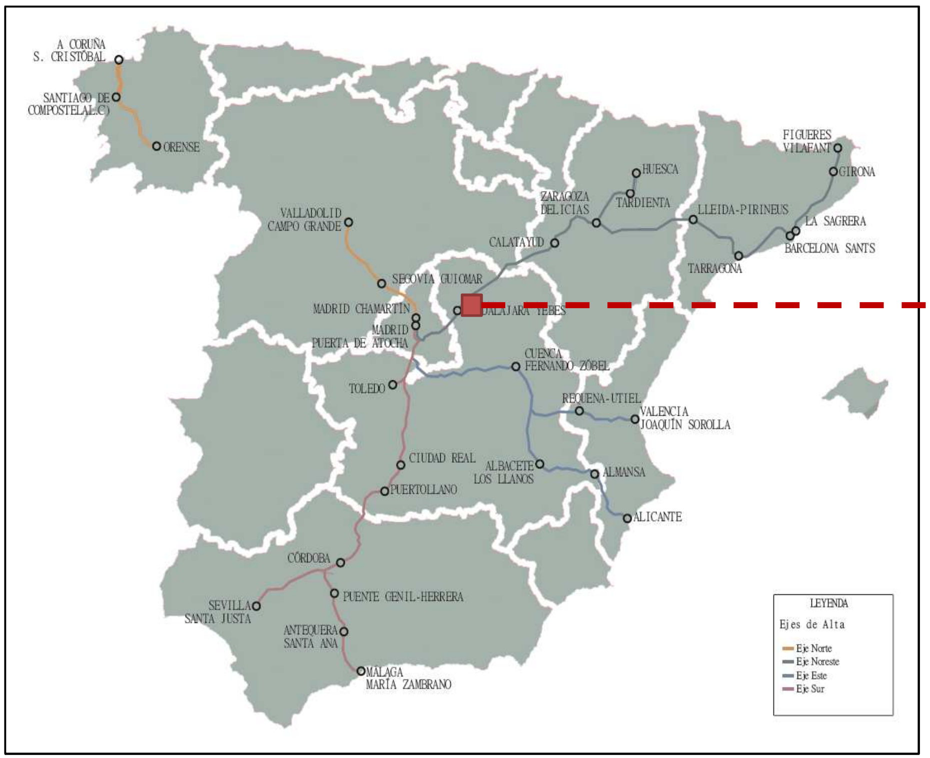
Track test at a frame with trains passing at a max speed of 358 km/h

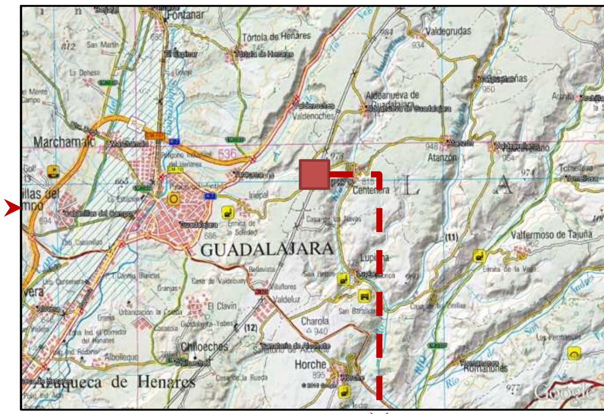
Adif, CEDEX and INECO

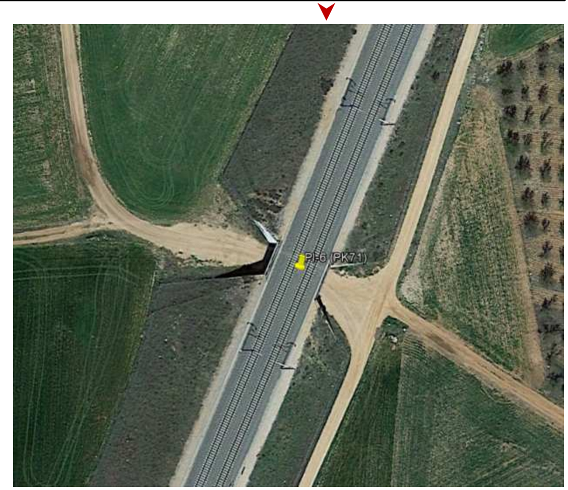
Sub-Task 1.2.3.2 Full scale tests

LOCATION

“Madrid – Zaragoza – Barcelona, French Border ”, High-speed railway line .
Underbridge PI-6, P.K. 71+968.

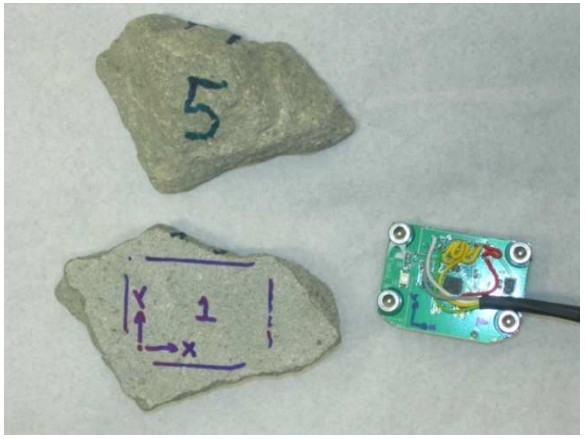


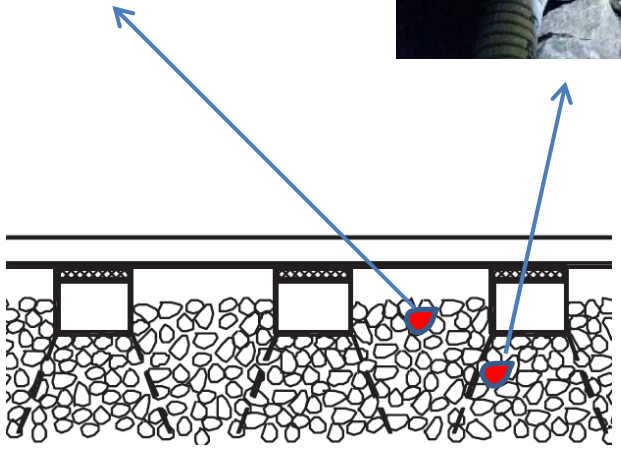




Sub-Task 1.2.3.2 Full scale tests

Adif carried out a study of ballast accelerations by means of accelerometers placed inside of real ballast particles. These ballast particles were placed in different positions and depths within the ballast layer above the frame.





Sub-Task 1.2.3.2 Full scale tests

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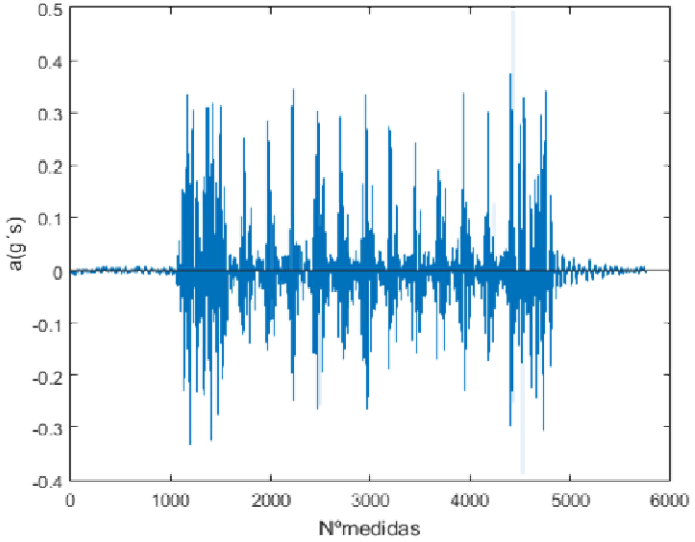
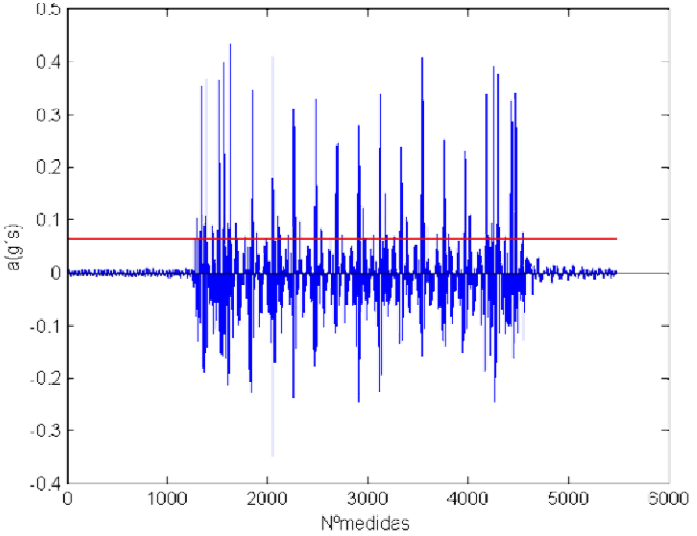
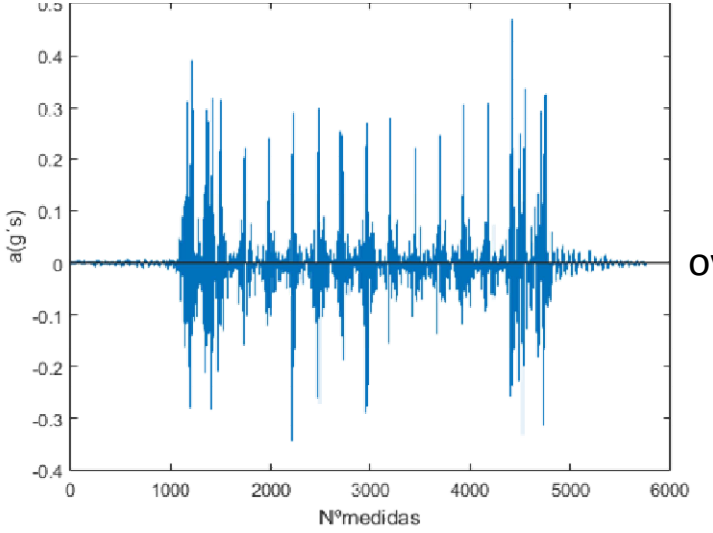
Ballast accelerations

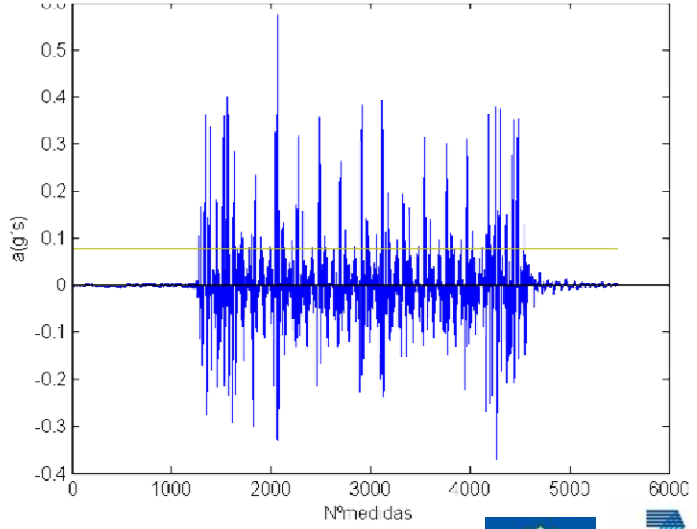


16 cm
under sleeper





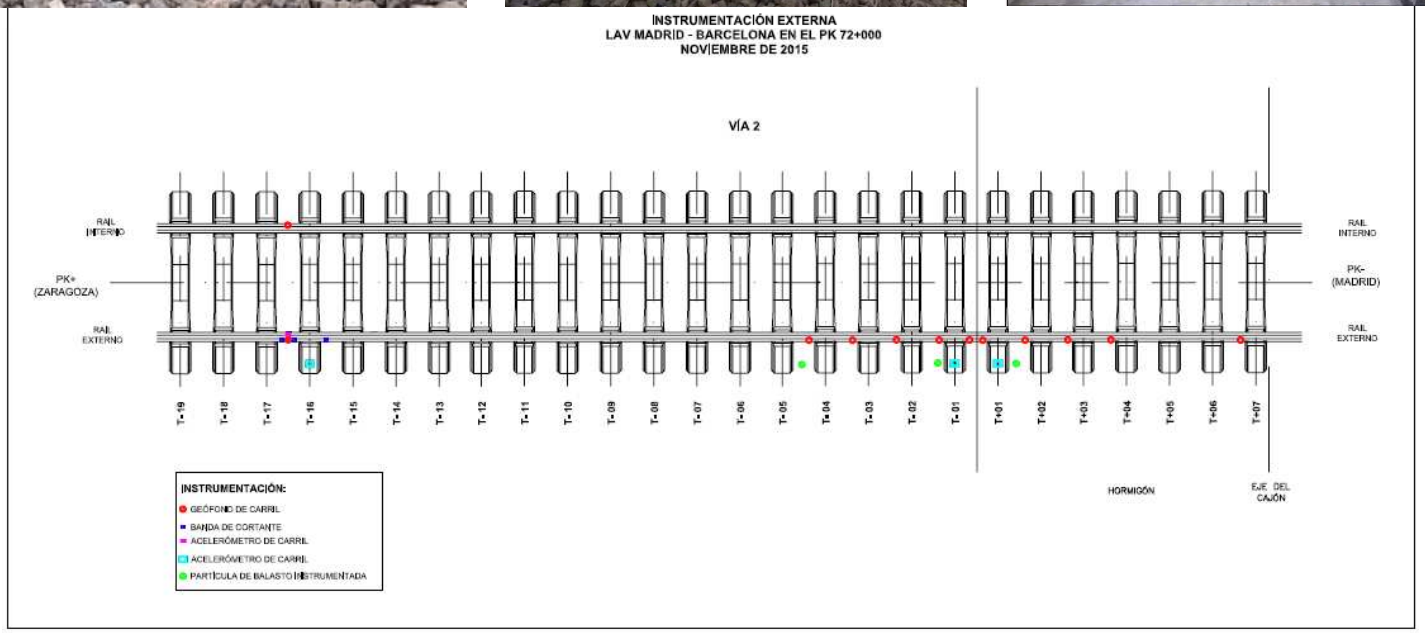
4 cm
over sleeper base



adif

Sub-Task 1.2.3.2 Full scale tests

CEDEX installation of geophones, accelerometers and strain gauges at Madrid – Barcelona HSL ,P.K. 71+968

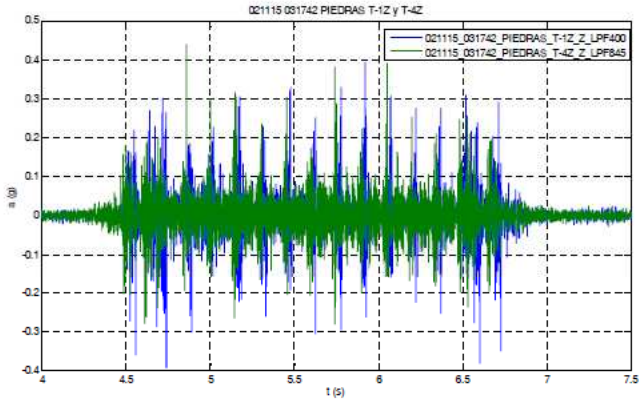


CEDEX

Sub-Task 1.2.3.2 Full scale tests

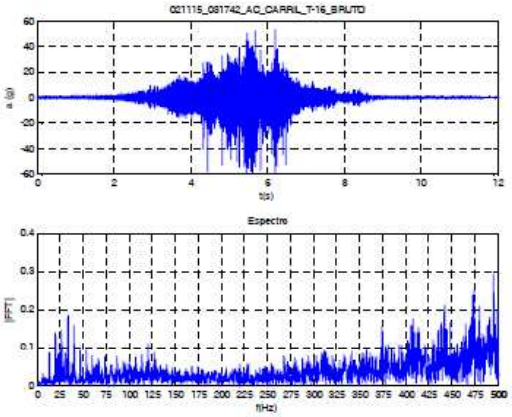
ACCELERATIONS:

At Ballast particle



At Rail

Raw



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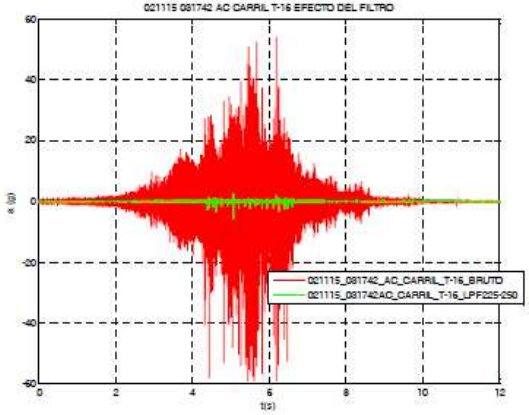
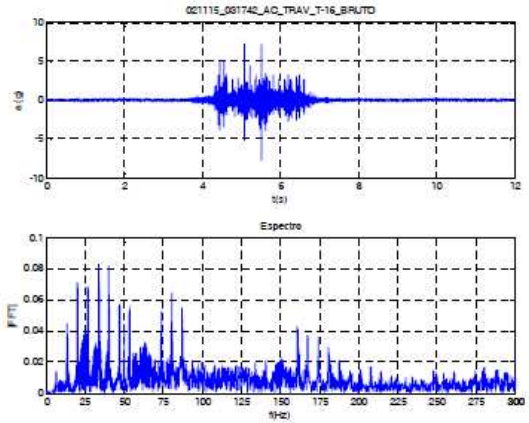


At Sleeper

Raw



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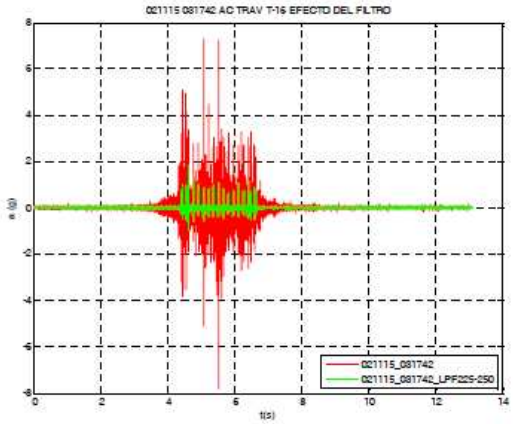
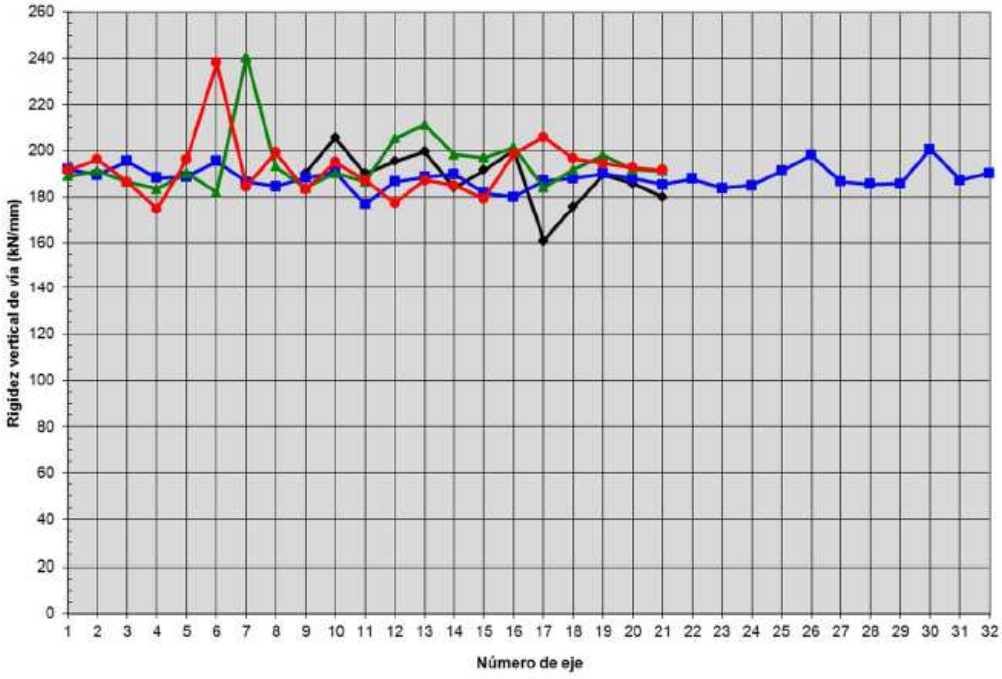


Sub-Task 1.2.3.2 Full scale tests

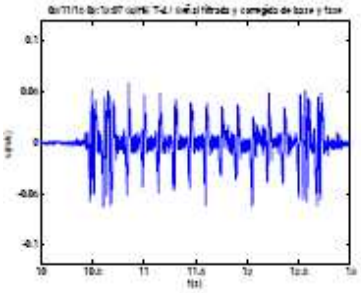
Capacity for Rail

TRACK VERTICAL STIFFNESS

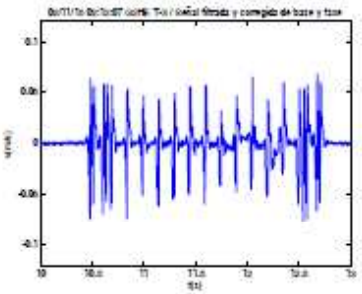


RAIL VIBRATION SPEED (GEOPHONES)

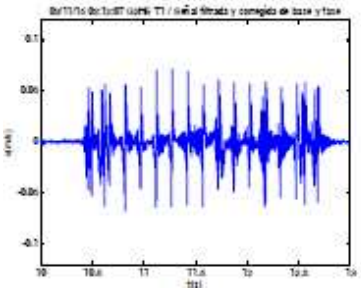
T-04



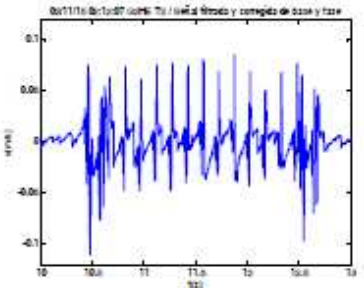
T-03



T+01



T+02



CEDEX

INECO INSTRUMENTATION

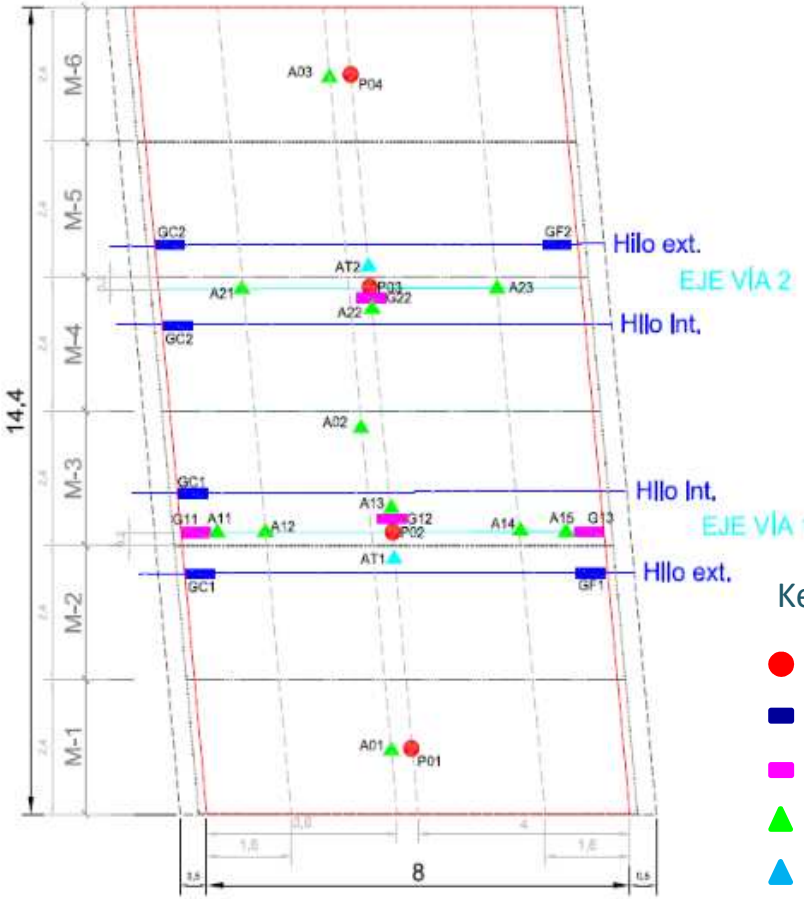
- Vertical displacement at the deck (Max. deflections). Total: 4 measuring points.
- Stress at the rail. 8 shear strain gauges and 2 bending strain gauges. Total: 10 measuring points.
- Stress at the deck. 4 bending strain gauges. Total: 4 measuring points.
- Accelerations at the deck. Total: 11 measuring points.
- Acceleration at sleepers. Total: 2 measuring points.

- Total measuring points monitored: 31
- Sampling frequency : 2,000 data per second

Capacity for Rail

INSTRUMENTATION SCHEME

MADRID ⇦



⇨ ZARAGOZA

Keys:

- DISPLACEMENT SENSOR
- STRAIN GAUGE AT THE RAIL
- STRAIN GAUGE AT THE DECK
- ACCELEROMETER AT THE DECK
- ACCELEROMETER AT THE DECK

ineco

Sub-Task 1.2.3.2 Full scale tests

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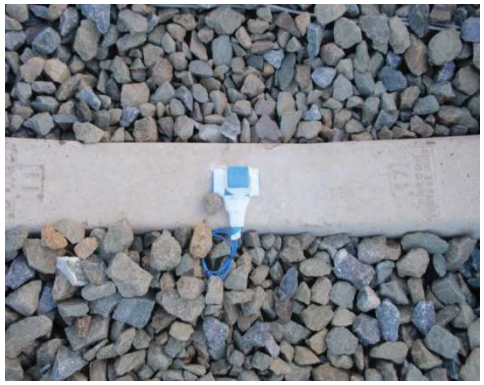
INSTRUMENTATION

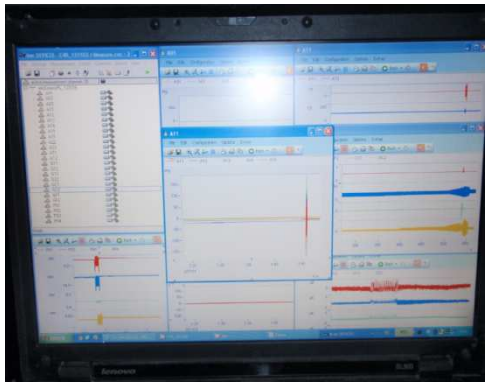
- Deflections at the deck.

- Accelerometer at the deck (lower side).

- Shear strain at the rail



- Accelerometer on sleeper.



- Recording screen in real time.

- Monitoring and recording equipment.

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Sub-Task 1.2.3.2 Full scale tests

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TESTS

- The tests were carried out on November 2nd, 2015, during maintenance work shift, with a **special testing train, called AVRIL**. Two train passages were monitored at the frame, one (return passage) on each track at different speeds, four train passages in total.
- Subsequently, several passages of commercial trains were monitored in order to provide additional data.
- The summary of all rail circulation is the following:

No.	TRAIN	TYPE	DATE	TIME	TRACK	SPEED	DESTINATION
1	AVRIL	Talgo	02/11/2015	0:39	1	317 km/h	Madrid - Medinaceli
2	AVRIL	Talgo	02/11/2015	1:41	1	358 km/h	Medinaceli - Madrid
3	AVRIL	Talgo	02/11/2015	2:10	2	312 km/h	Madrid - Medinaceli
4	AVRIL	Talgo	02/11/2015	3:16	2	317 km/h	Medinaceli - Madrid
5	Comercial 01	S103	02/11/2015	6:52	1	277 km/h	Madrid - Medinaceli
6	Comercial 02	S103	02/11/2015	7:23	1	252 km/h	Madrid - Medinaceli
7	Comercial 03	S103	02/11/2015	7:34	2	198 km/h	Medinaceli - Madrid
8	Comercial 04	S103	02/11/2015	7:41	1	253 km/h	Madrid - Medinaceli

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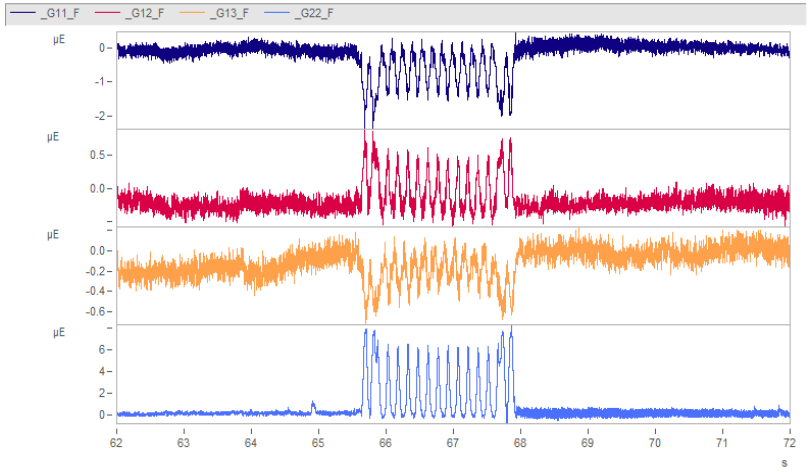
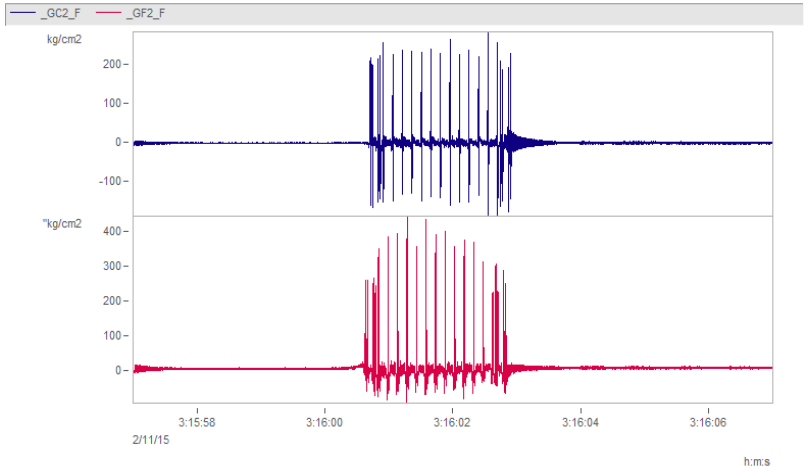
SEVENTH FRAMEWORK PROGRAMME

STRAIN MEASUREMENT RESULTS.

- Graphic recording of the last train passage, on track 2, Medinaceli-Madrid bound, at 317 km/h.





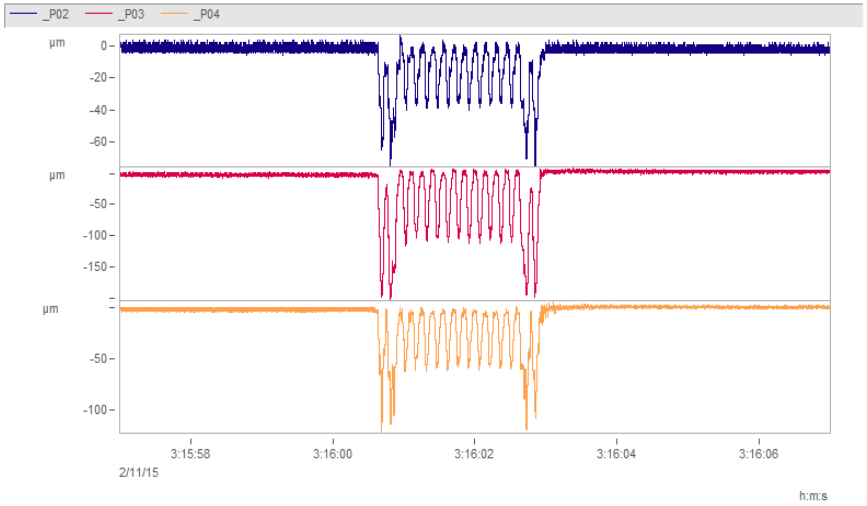
- Maximum values during the 4 passages of the testing train.

Deck Strain	Unit	Absolute Maximum
G11	με	2,3
G12	με	2,1
G13	με	2,2
G22	με	8,0

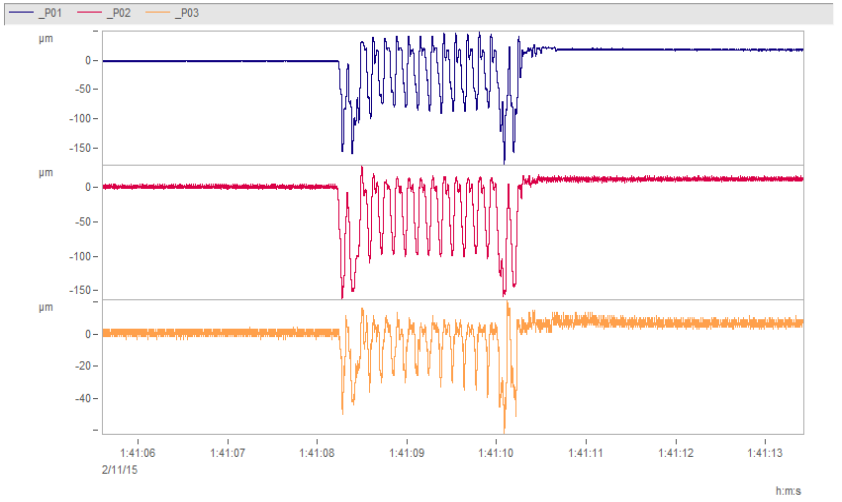
Rail Strain	Unit	Absolute Maximum
GC1	kg/cm2	313
GC2	kg/cm2	363
GF1	kg/cm2	513
GF2	kg/cm2	466

DEFLECTION MEASUREMENT RESULTS.

- Graphic of the last passage of the test train on track 2, Medinaceli-Madrid bound, at 317 km/h.



- Graphic of the last passage of the test train on track 1, Medinaceli-Madrid bound, at 358 km/h.

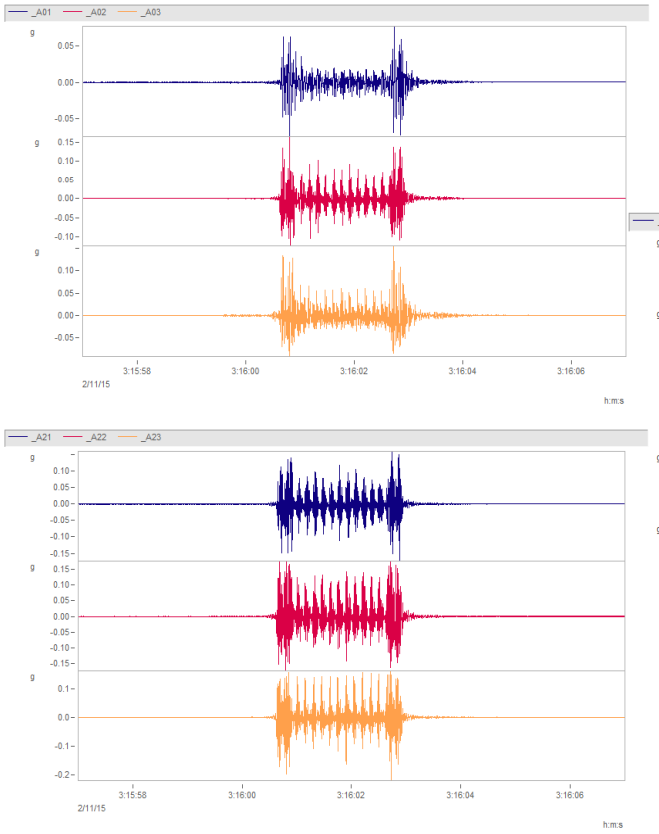


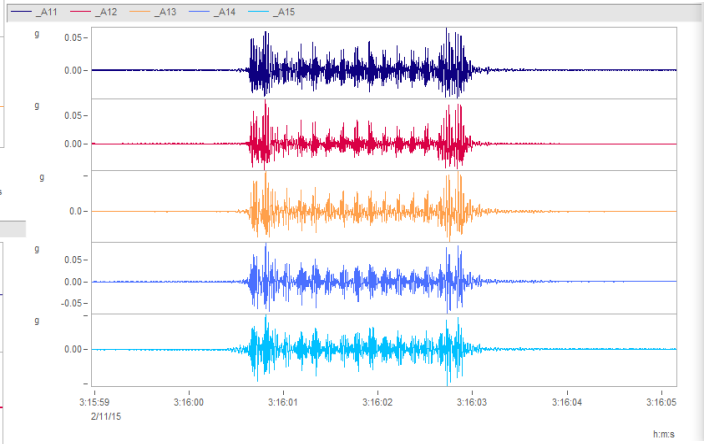
- Maximum values during the 4 passages of the test train.

Deck displacement	Unit	Absolute Maximum
P01	mm	0,18
P02	mm	0,17
P03	mm	0,21
P04	mm	0,12

ACCELERATION MEASUREMENT RESULTS

Graphic of the last passage of the test train on track 2, Medinaceli-Madrid bound, at 317 km/h.





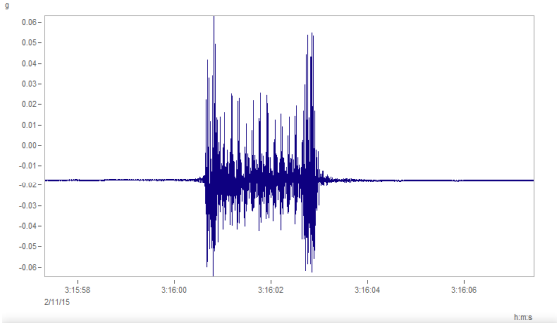
- Maximum values during the 4 passages of the test train.

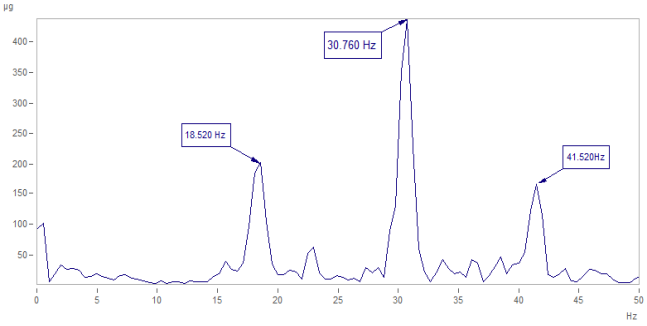
Sleeper acceleration	Unit	Absolute Maximum
AT1	g	3,86
AT2	g	3,96

Deck Acceleration	Unit	Absolute Maximum
A01	g	0,19
A02	g	0,16
A03	g	0,17
A11	g	0,12
A12	g	0,16
A13	g	0,19
A14	g	0,17
A15	g	0,18
A21	g	0,19
A22	g	0,18
A23	g	0,24

ACCELERATION RESULTS.

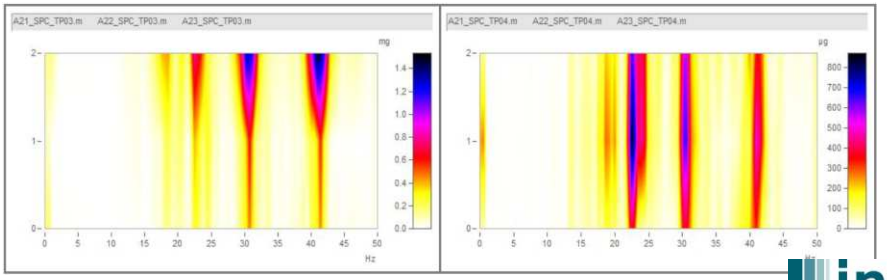
- The main frequency and spectrum have been obtained during each test train passage for each of the accelerometers installed on the structure.



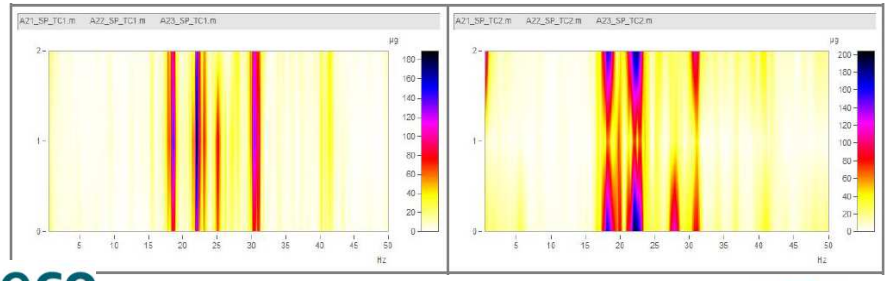


	Ud.	PASADA 01	PASADA 02	PASADA 03	PASADA 04
A01	Hz	30,27	30,76	30,27	30,27
A02	Hz	30,27	30,76	30,27	30,27
A03	Hz	30,76	30,76	30,27	30,27
A11	Hz	31,25	30,76	30,27	30,27
A12	Hz	31,25	30,76	30,76	30,27
A13	Hz	30,27	30,76	30,27	30,27
A14	Hz	30,27	30,76	30,76	30,76
A15	Hz	30,27	30,76	30,76	30,76
A21	Hz	22,95	30,76	41,02	41,02
A22	Hz	22,95	30,76	22,46	41,02
A23	Hz	22,95	30,76	22,46	22,46

- Accelerometer spectrograms on track 2 on the 3rd and 4th passage of the test train (on track 2 and both ways).



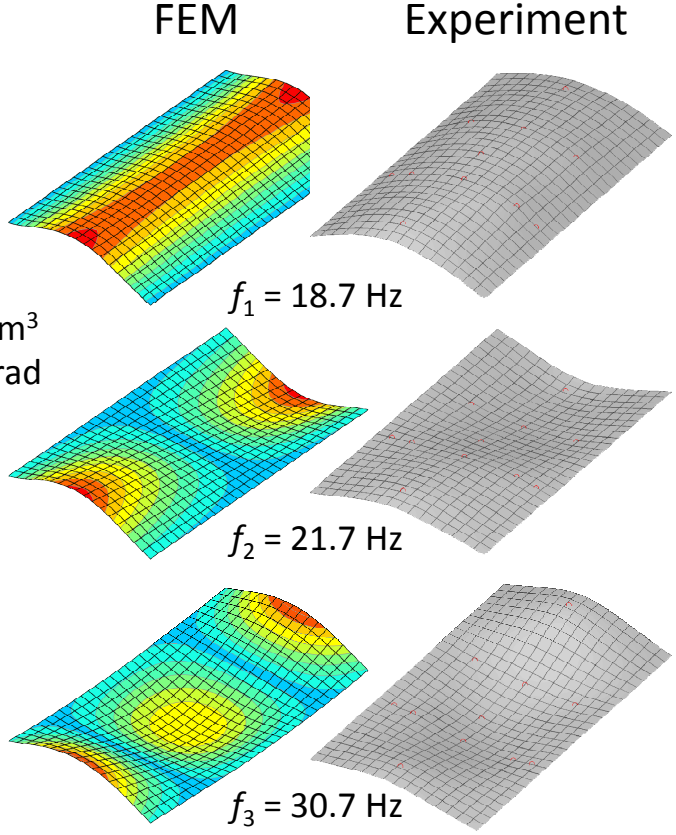
- Accelerometer spectrograms on track 2 on the 1st and 2nd passage of commercial trains (on track 1 and both ways).

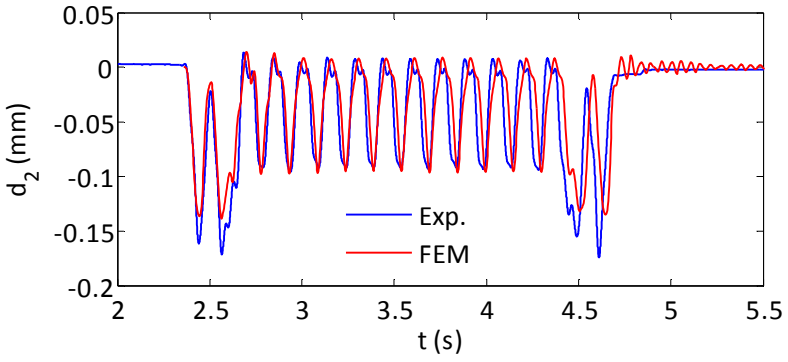


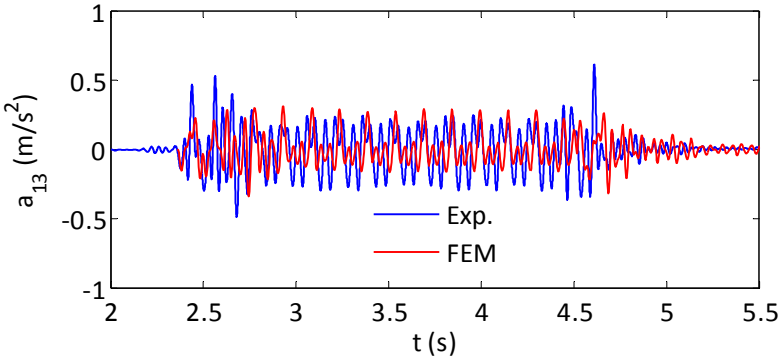
Bridge test Spain (analysis by KTH)

- Experiment
  - Modal properties, free vibration
  - Acc and disp from train passage, Talgo Avril at 312 km/h
- FEM
  - Skewed slab on elastic supports
  - Support stiffness K_φ and K_δ
  - Orthotropic deck, $E_{c,II}$ and $E_{c,\perp}$
  - Equivalent mass, incl. ballast
  - Automatic model updating, f_1, f_2, f_3
  - Train passages, disp and acc.

FE-model:
$E_{c,II}$ = 32 GPa
$E_{c,\perp}$ = 14 GPa
ρ_{eq} = 4000 kg/m^3
K_φ = 21 GNm/rad
K_δ = 34 GN/m







C4R SP1 WP1.2

Task 1.2.3 Structures dynamical effects due to very high speed

Sub-Task 1.2.3.1 Calculation methods and models.

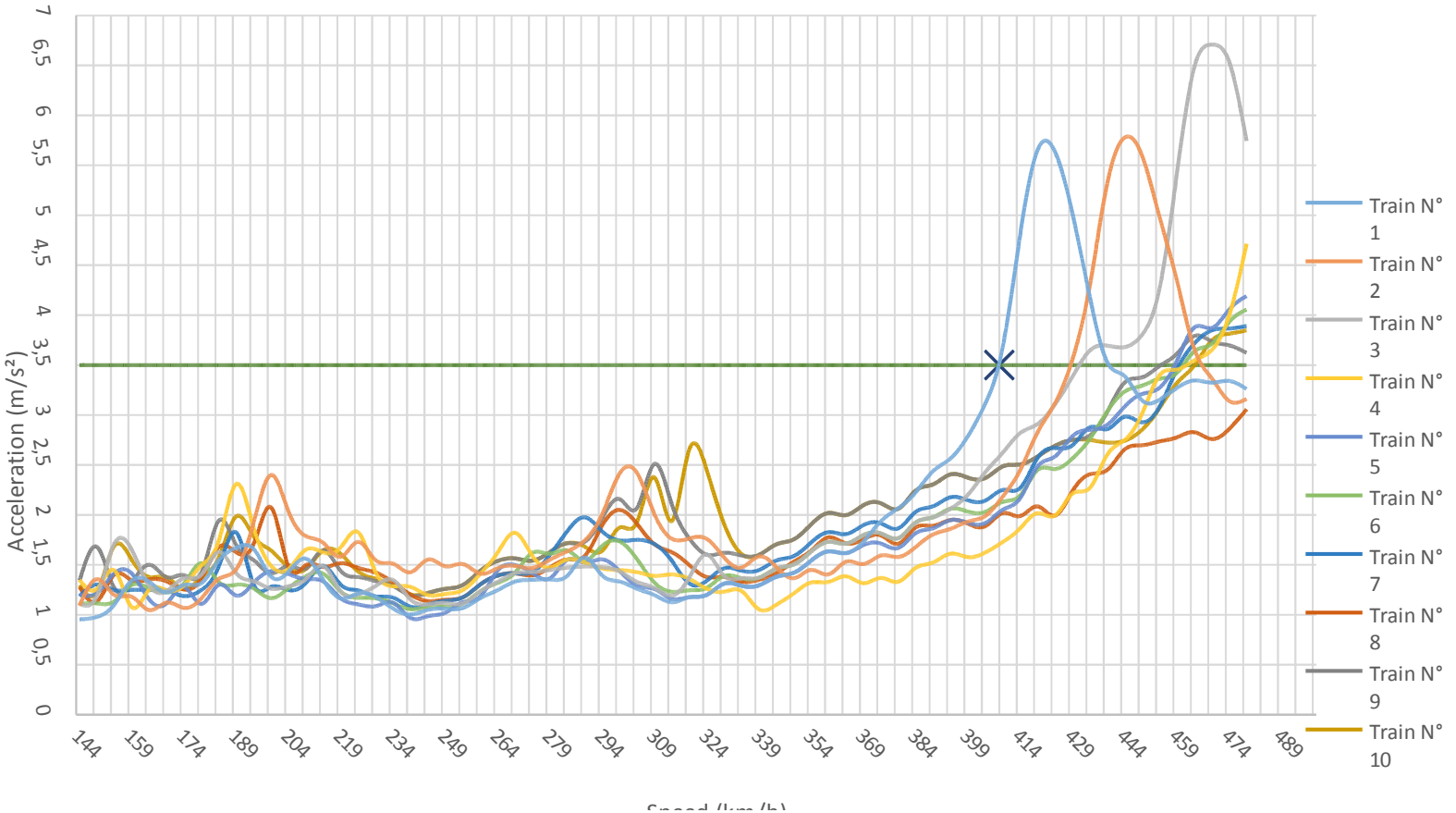
Deck and rolling stock acceleration function of train speed.

Serge Montens

Sub-Task 1.2.3.1 Calculation methods and models.

Capacity for Rail

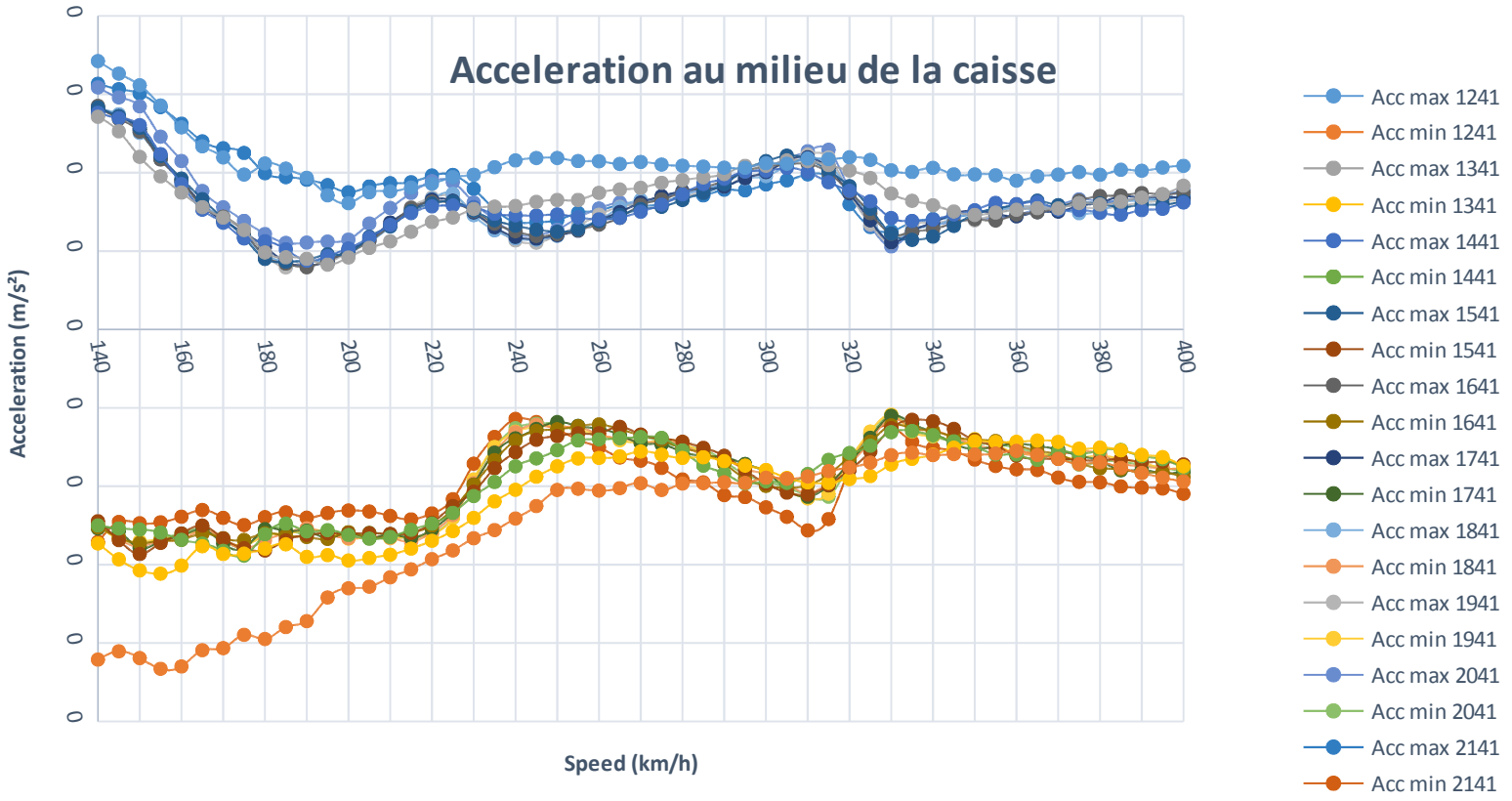
Example of deck acceleration function of train speed for HSLM trains



SYSTRA

Capacity for Rail

Example of rolling stock acceleration function of train speed



Thank you for your kind attention

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