Understanding Critical Velocity Effects On High-Speed Railways

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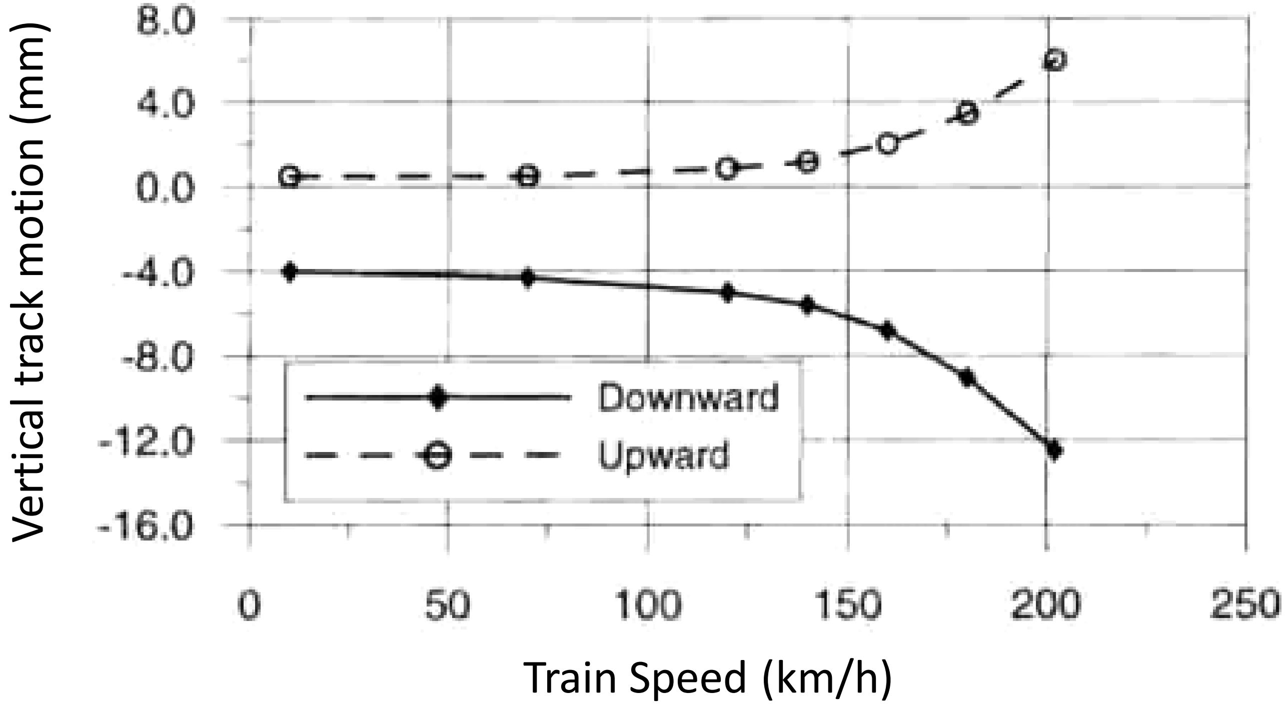
What are critical velocity effects…



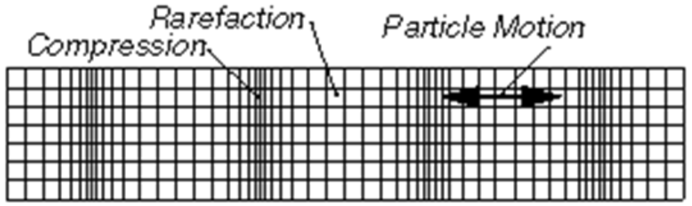
Madshus and Kaynia, 2000

- Excessive track and ground movement and vibration beneath train passage
- Speed of onset of extreme movement named ‘critical speed/velocity’

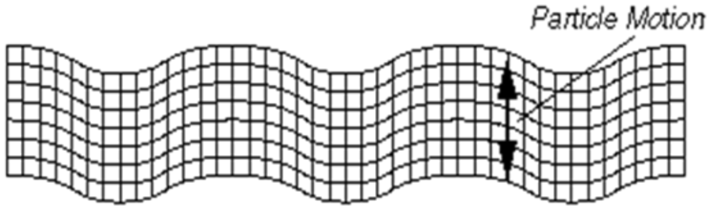
Why are they a problem…

- Cause track and substructure damage
- Increased maintenance required
- Train running speeds may have to be lowered
- Bad press

What causes critical velocity effects….



Compressional or P Wave



Shear or S Wave

Rayleigh Wave

Rayleigh = 90 to 95% of Shear

- Effects occur where train speed approaches or exceeds the grounds Rayleigh wave speed
- Rayleigh wave = combination of P and S waves
- Areas of soft material, e.g. peat or organic clay, can have shear wave speeds as low as 30 ms^{-1}, much lower than train speeds.

Project Aims:

- Improved understanding of the influence of various geotechnical parameters on critical velocity effects
- Aid in the improvement of :
  - the identification of potentially problematic locations,
  - simulation of track performance in pre and post-remediated states.

Project Areas:

Lab Testing:

- Standard density, moisture content etc measurements
- RC , BE & CT – stiffness, damping and wavespeeds, inc. variation with stress/strain and frequency

Movement and vibration prediction and mitigation design

Field Instrumentation

- Ground vibration
- MASW – estimates of wavespeeds and stiffness profiles
- Sleeper movement

Models

- WANDS: 2.5D FE/BE
- MOTIV: 2.5D semi-analytic
- More complex 3D models and non-linear models under development

Impact of parameter knowledge:

Very stiff

- no problem

Intermediate stiffness

- borderline problem
- linear modelling likely
- Remediation scoped in or out

Very soft

- obvious problem
- non-linear modelling likely (difficult, time-consuming)
- Remediation guaranteed

Potential for improvement / savings through improved parameter knowledge

Case Study Sites:

Very stiff

Intermediate stiffness

Very soft

Site B

- Ground movement ok at standard speeds
- Soft clays

Site A

- Excessive ground movement at high speed (200 kmh^{-1})
- Peat

Case Study Sites:

Site A

- Train movement measurements
- Very limited seismic measurements
- Boreholes
- Dynamic heavy probe
- Window sampling (2-3 bores, 6m depth). Peat

Site B

- Train movement measurements
- MASW measurements
- Boreholes
- Window sampling (2-3 bores, 6m depth). Soft clay

HS2

- Boreholes
- Future sampling type – unknown – soft clays?
- Possible seismic measurements

Site Monitoring – A:

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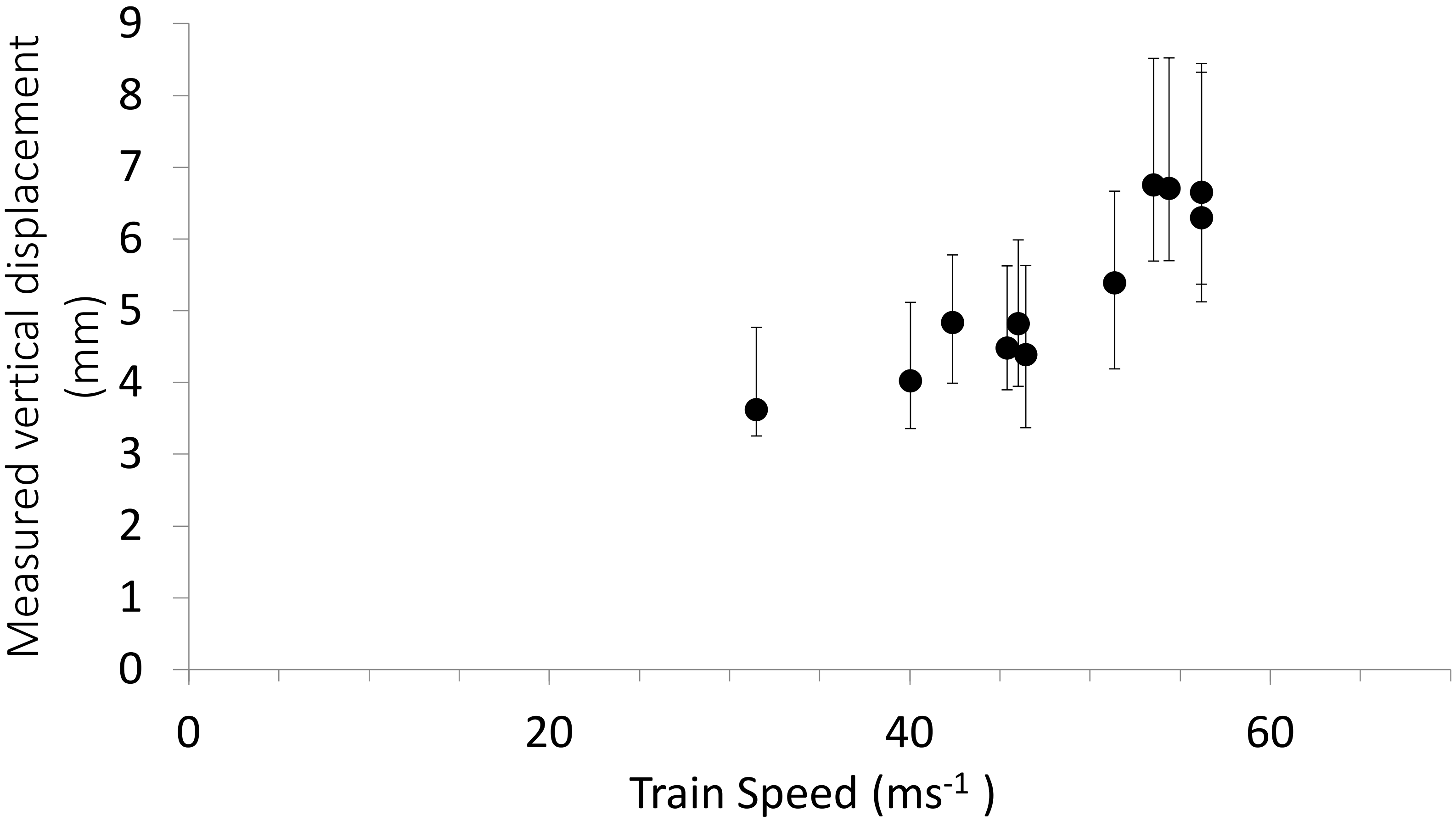


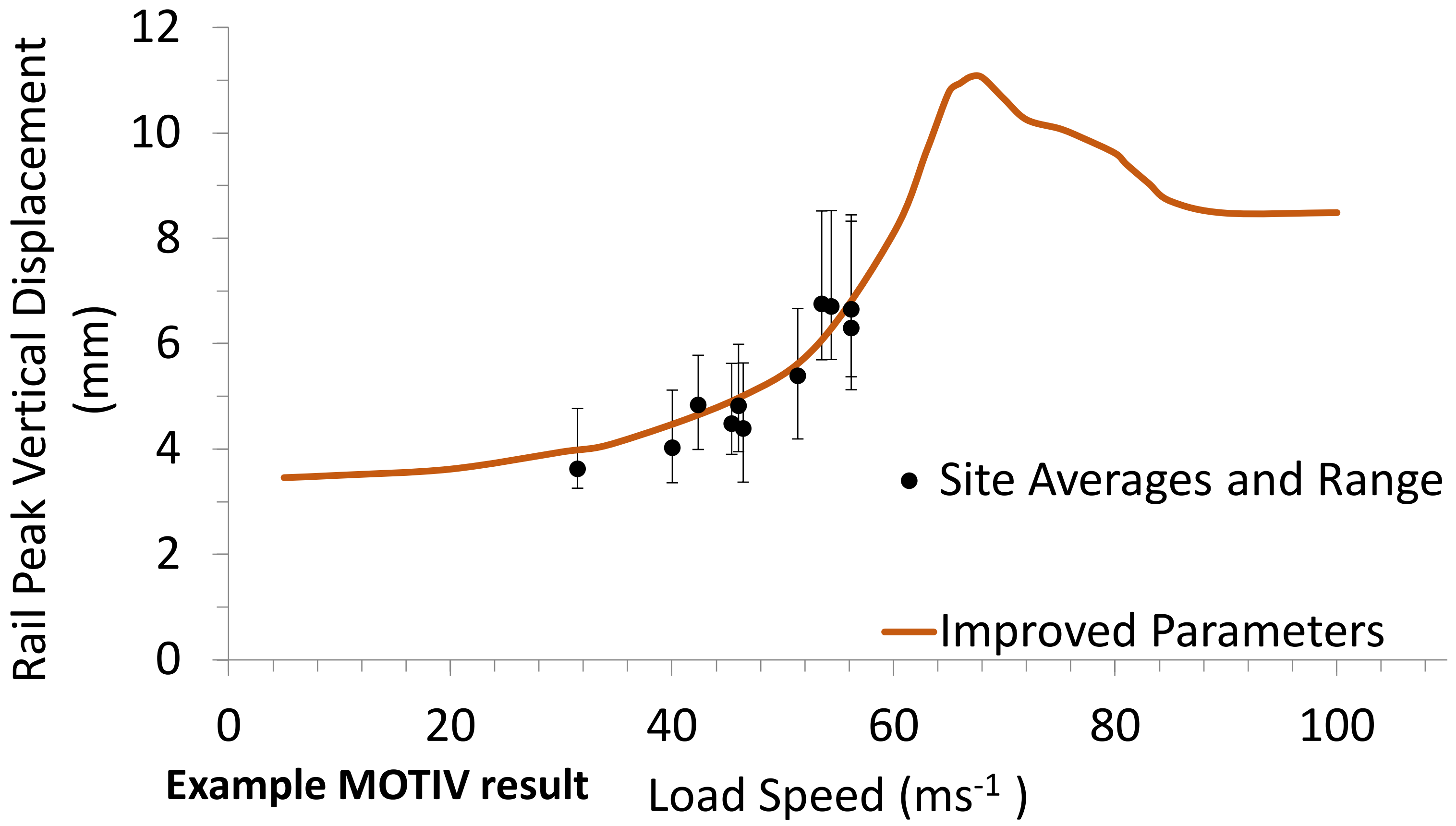
Previous Site Modelling – A:

WANDS:

- 2.5D FE/BE
- Wavenumber domain
- Track: FE ; Ground: BE

MOTIV:

- 2.5D semi-analytical
- Wavenumber domain
- Ground: Layered halfspace



Example MOTIV result

Lab Testing:

- Wavespeeds
- Damping
- Stiffness
- Non-linearity effects

Sample sizes:
38 , 50 or 70 mm diameter, up to 140 mm in height

Resonant Column

Geotechpedia, 2012

Bender Elements

Triaxial

GDS Instruments , 2016

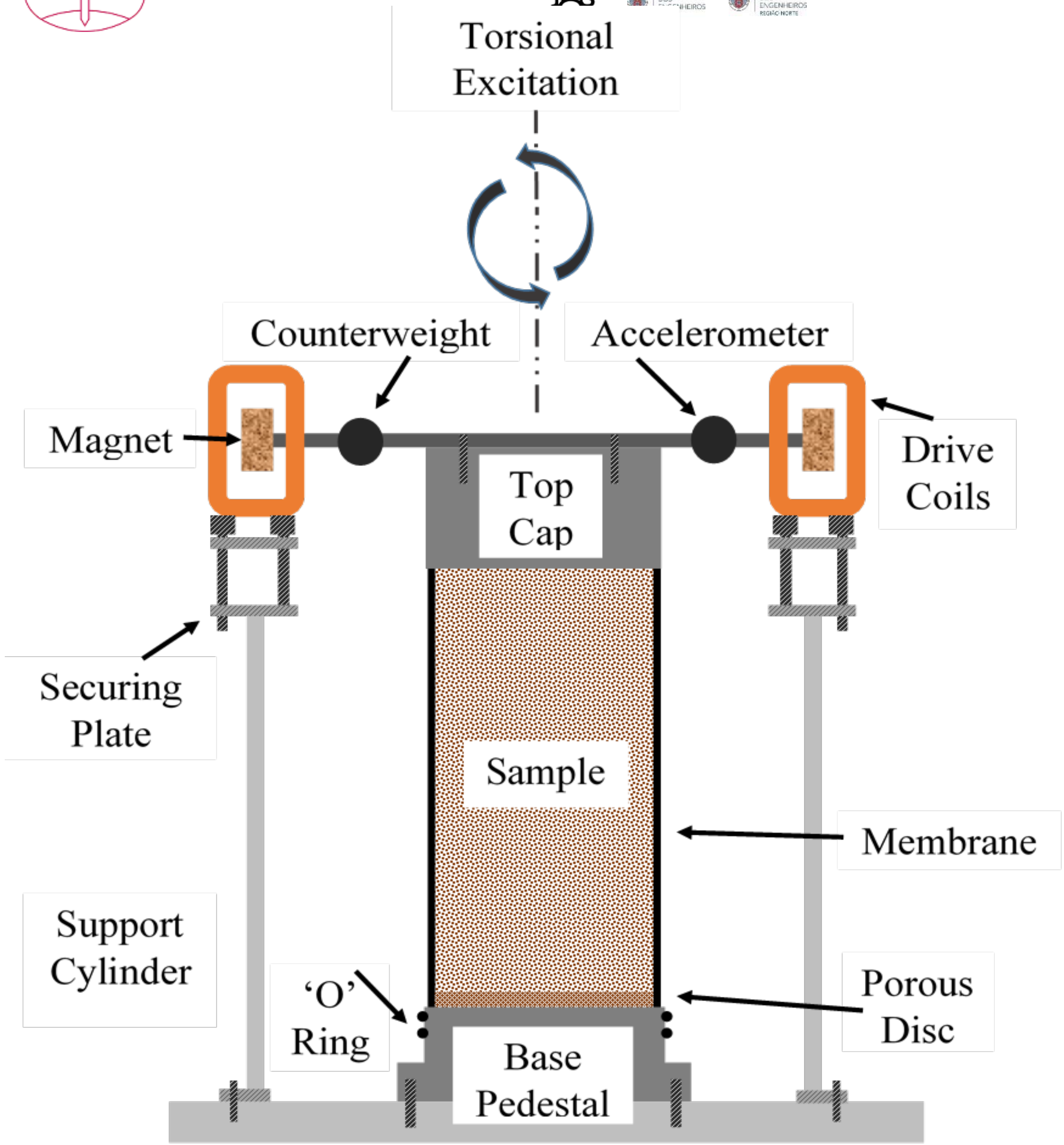
Resonant Column:

Provides key model inputs:

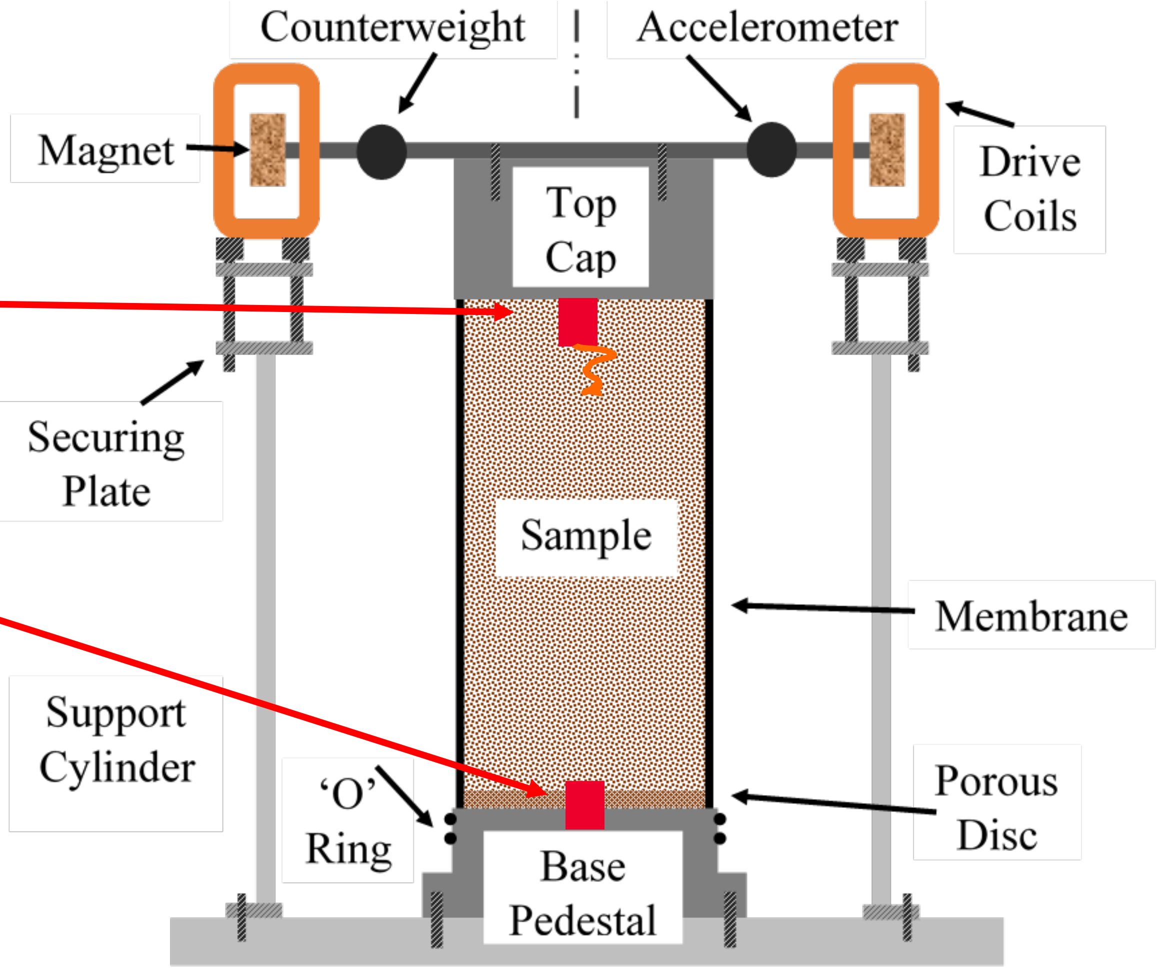
- Shear wave,
- compressional wave ,
- damping.
- (Shear modulus, Young's modulus)

Tests at varied strains -

- Shear modulus degradation curves – Strain dependant stiffness



Bender Elements:



Shear wave (and shear modulus) measurements → Comparison to RC values (at similar frequencies)

Triaxial:

Testing outputs:

- Critical state framework parameters - relatively untested materials

- Shear modulus degradation with strain – complex model inputs, also shows if non-linearity expected at site strains

Conclusions:

- Ground stiffness and shear wave speeds are essential parameters when modelling critical velocity effects.
- Accurate estimation of these parameters is essential when considering possible mitigation measures for marginal sites.
- Laboratory testing on a range of site samples will be carried out, and the resulting impact on model accuracy assessed.
- A combination of case studies, laboratory testing and modelling will provide recommendations for how best measure/predict key parameters for use in relatively ‘simple’ linear elastic models used as scoping tools.

Thankyou for listening!

References

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