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SUBSURFACE EXPERTISE

Impact of Ground Vibrations from Passing Trains to the Nearby Buildings

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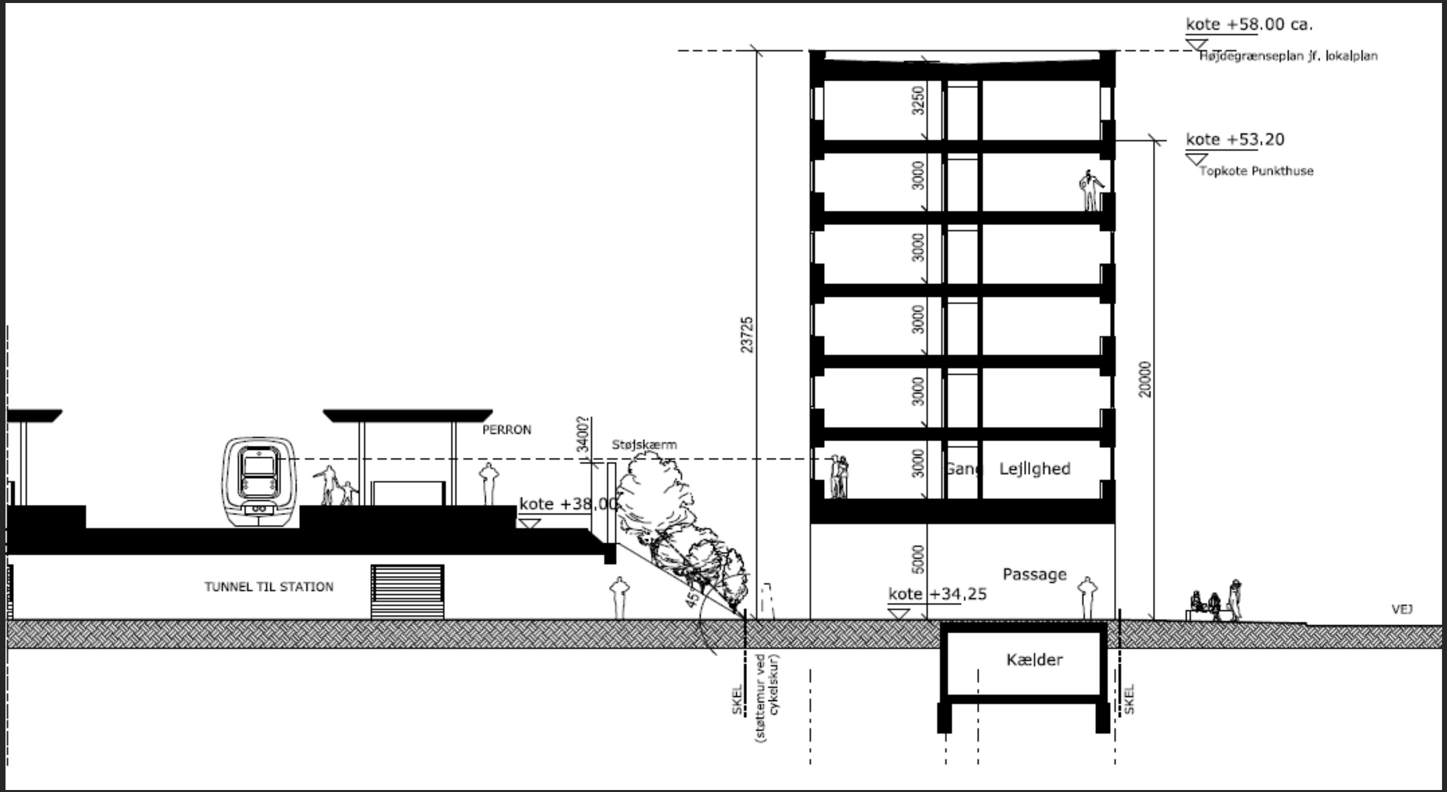
AARHUS UNIVERSITY

Impact of Ground Vibrations from Passing Trains to the Nearby Building

Railway track & building cross section + Some of the Guidelines



Danish guidelines on environmental low frequency noise, infrasound and vibration

Jorgen Jakobsen
Danish Environmental Protection Agency, Industrial Section, Strandgade 29, DK - 1401 Copenhagen K, Denmark

Received 2 March 2001

Table II. Recommended limits for vibration, given both as the weighted acceleration level in dB re 10^{-6} m/s², weighted vibration (mm/s²), and the corresponding weighted velocity (mm/s)

	Weighted acceleration level, L_{aw}	Weighted acceleration a_w	Corresponding weighted velocity v_w
Dwelling in residential areas (day and night) or In mixed areas (evening & night), institution	75 dB	5.6 mm/s²	0.16 mm/s
Dwelling in mixed areas (day), office and classroom	80 dB	10 mm/s²	0.3 mm/s
Other rooms in enterprises	85 dB	17.8 mm/s²	0.5 mm/s

ORIENTERING FRA MILJØSTYRELSENS REFERENCELABORATORIUM FOR STØJMÅLINGER

Genevirkning af vibrationer

Orientering nr. 49 PFi/THP/ilk 27. januar 2014

ISO 2631-1 : 1997

MECHANICAL VIBRATION AND SHOCK — EVALUATION OF HUMAN EXPOSURE TO WHOLE BODY VIBRATION

PART 1 GENERAL REQUIREMENTS

- Near a train station, less than 10 m from the railway, a new multistory concrete building is to be built. In this connection, acc. to the guidelines / regulations, an assessment of the vibration level, (through the foundation to the top floor), due to passing trains, has to be carried out.
- Vibration measurements for a number of trains have been conducted at the site, 15 m from the railway among other distances.
- Considering railway and building geometry along the railway, 2D plane strain dynamic FE modeling in Plaxis is applied to calculate the vibrations from the track, through the embankment and interpreted 2-layers soil model, with the vibration measurements being used to adjust the dynamic FE model, as well as to assess the magnitude of a generalized stationary dynamic load on the track.
- In this process, the soil conditions are interpreted from the available Geo boreholes carried out at the building site.

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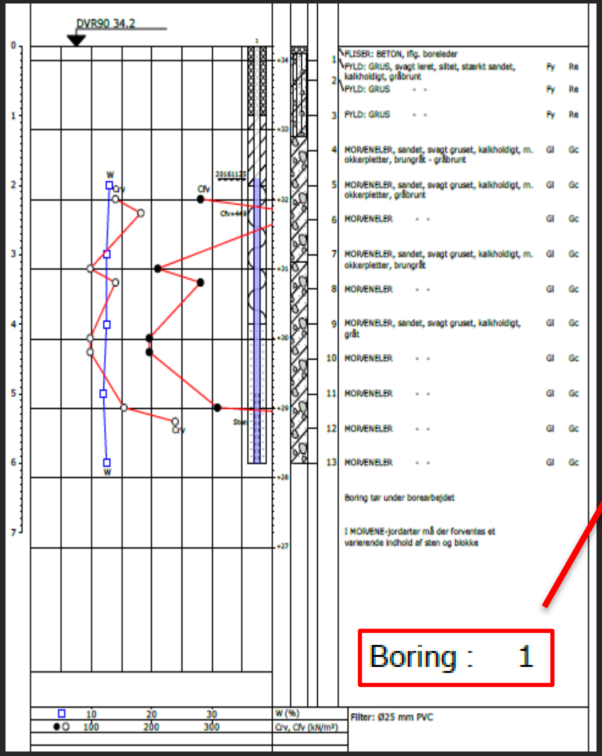
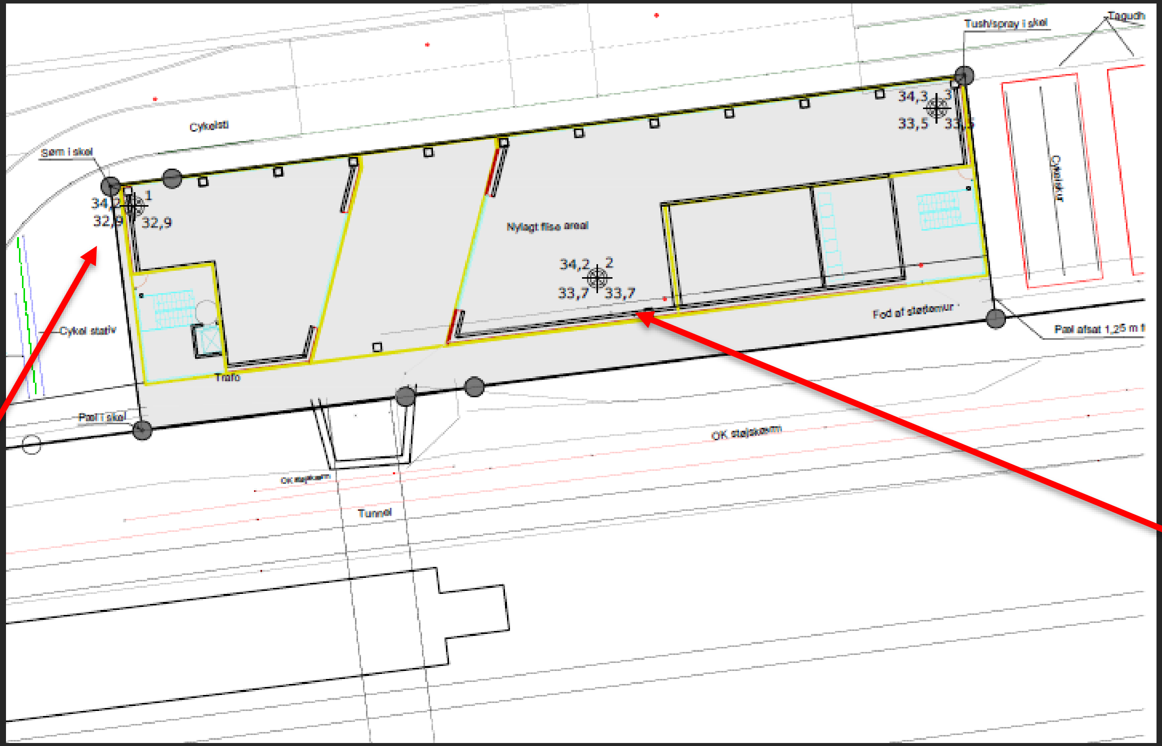
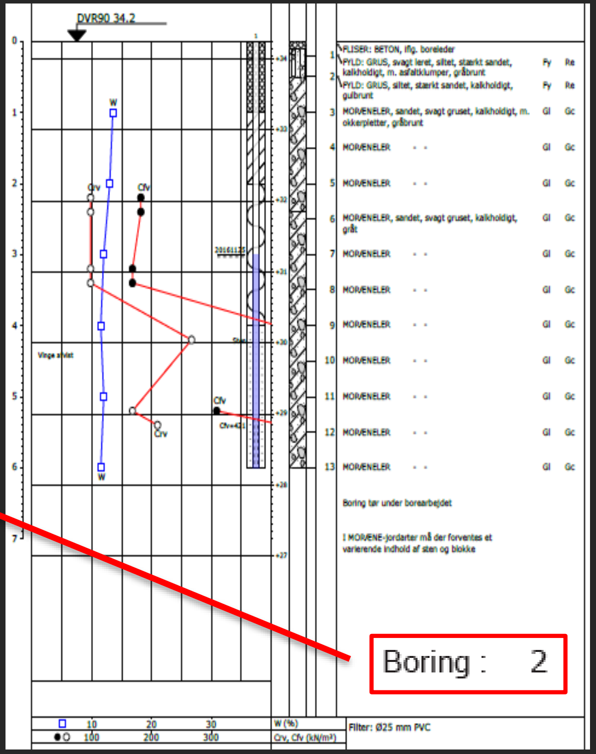
Location plan and soil data / Geo boreholes – Soil variation + Interpretations







Characteristic Strength and Deformation Parameters

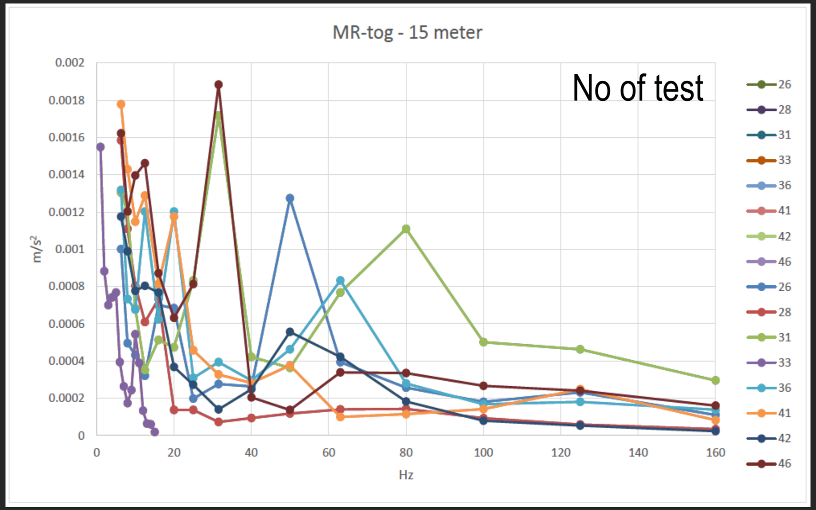
Soil Type	Top Elevation [m]	Thickness [m]	Unit Weight γ/γ' [kN/m³]	Strength parameters φ'ₖ [°]	Strength parameters c'ₖ [kPa]	Deformation parameters E_{oed} [MPa]
Embankment	+38	3.8	21/11	30	10	10/50
Clay Till / Moræneler over +29	+34.2	5.2	21/11	30	10	30/150
Clay Till / Moræneler under +29	+29	29	21/11	32	15	60/300

Permanent water table standing at elevation +31.2 m.

Vertical vibration measurements and calculations from dB to m/s^2

15 m from the railway, 0.4 m depth – Point A in the FE model

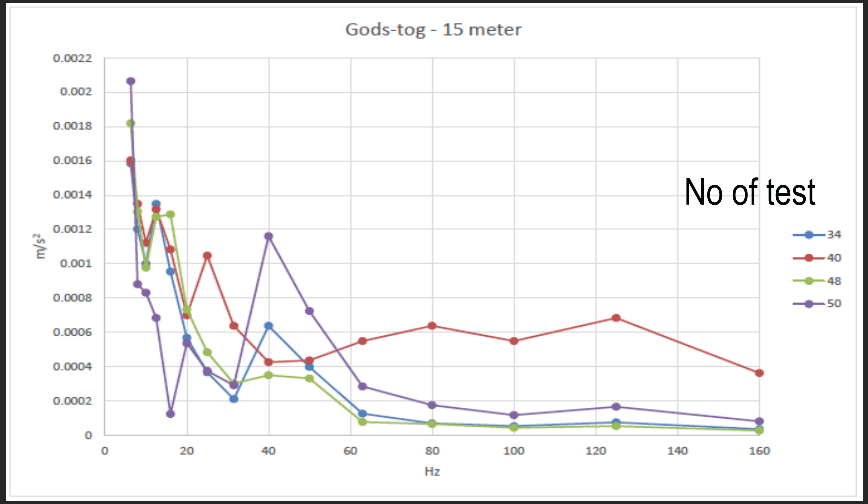
Horizontal vibrations are very small

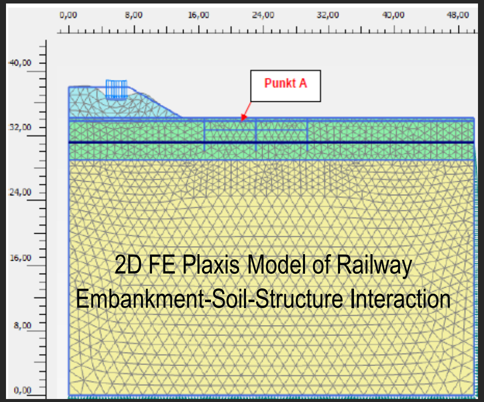


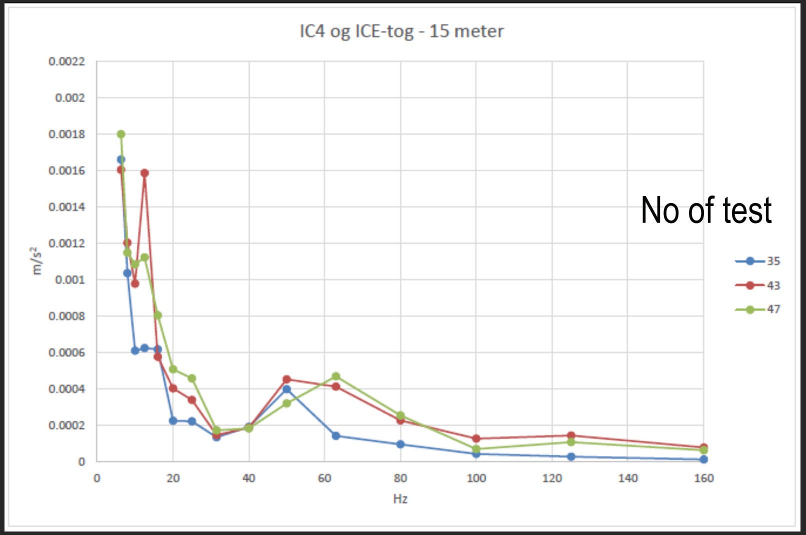
The results of the vertical vibration measurements are received as the KB-weighted vibration level (Law) in dB re 10^{-6}. These data are converted into accelerations (a1) according to:

$$dB = 20 \cdot \log\left(\frac{a_1}{a_0}\right)$$

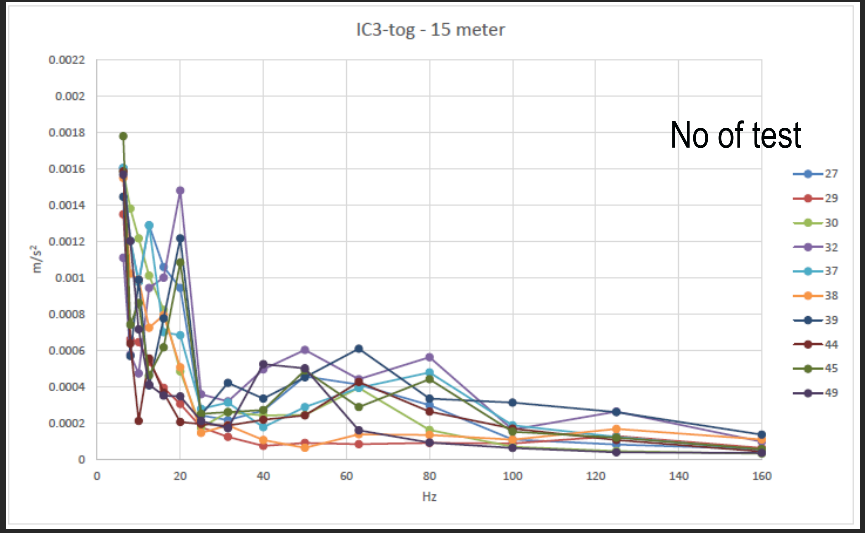
$$a_0 = 10^{-6}\, m/s^2$$



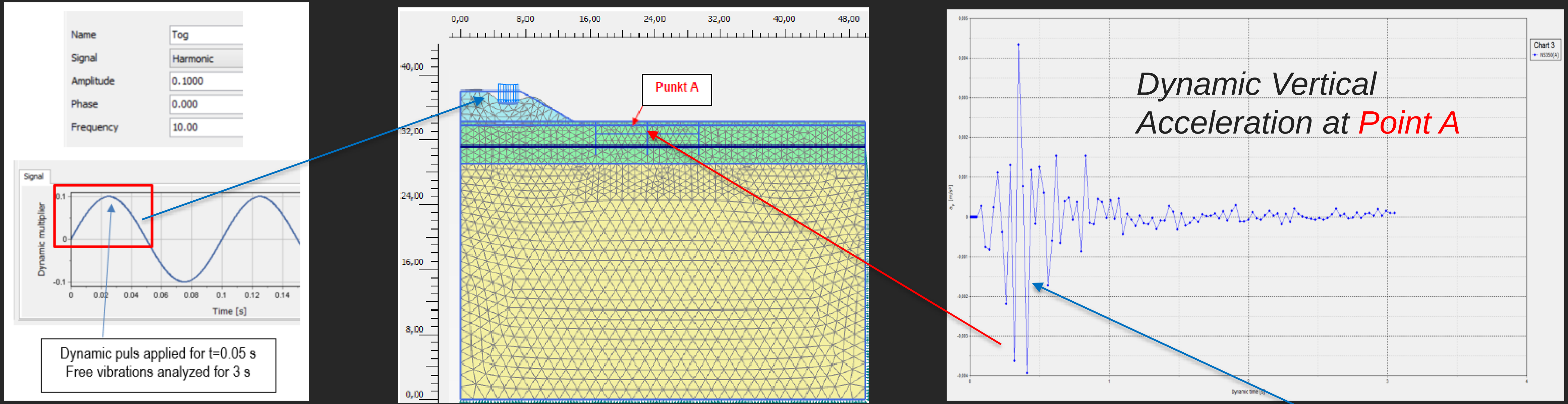


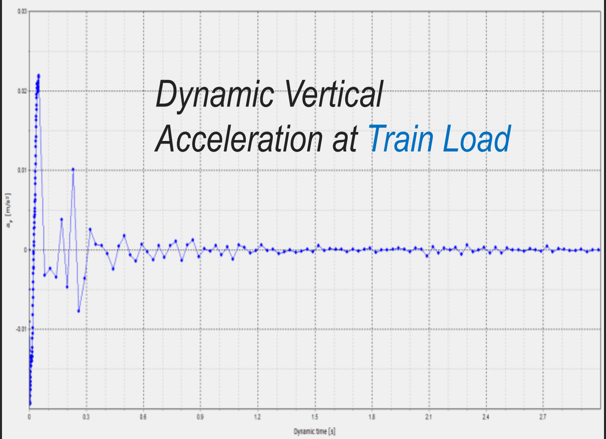


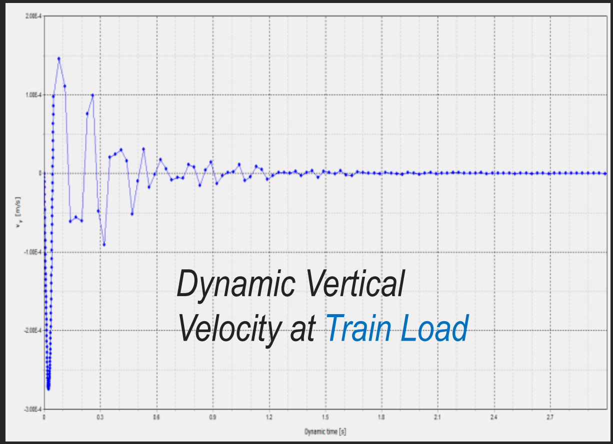
The biggest impacts are within the frequency range around (5–15) Hz, i.e. precisely within the area where the frequency weighting curves in the guidelines indicate that the acceleration signals must not be corrected.

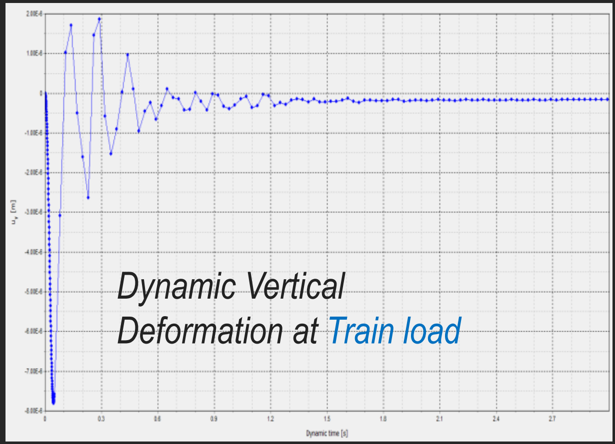


The current dynamic trainload from the passing trains is not known. Therefore, it is simplified to a stationary (non-moving) dynamic pulse with a dominant frequency of 10 Hz, thus disregarding the effect of train velocity









The largest vertical vibration level measured is 71.5 dB, corresponding to vertical acceleration of 0.0038 m/s2. This level in aimed to be achieved in the dynamic model by iteratively determining the vertical dynamic load from the passing train over a period of half a load cycle, of free vibrations for 3 s

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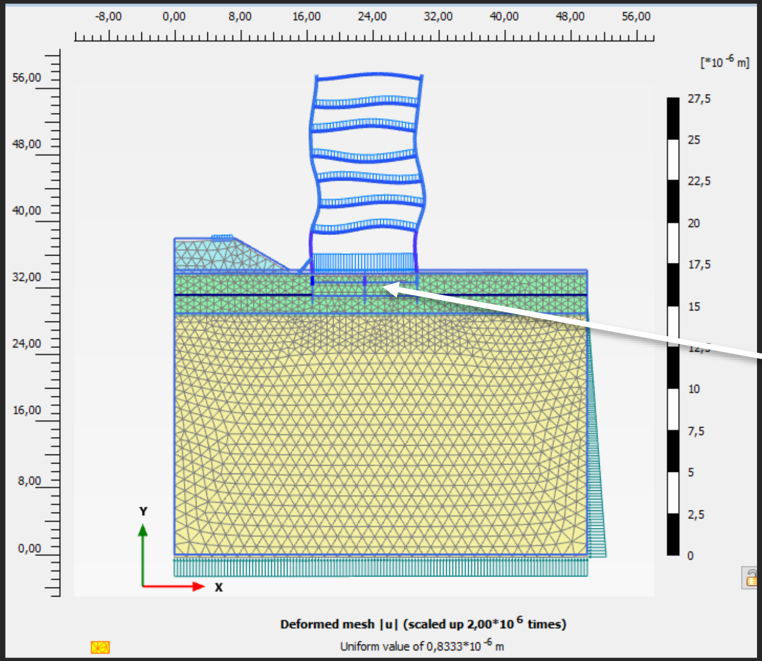
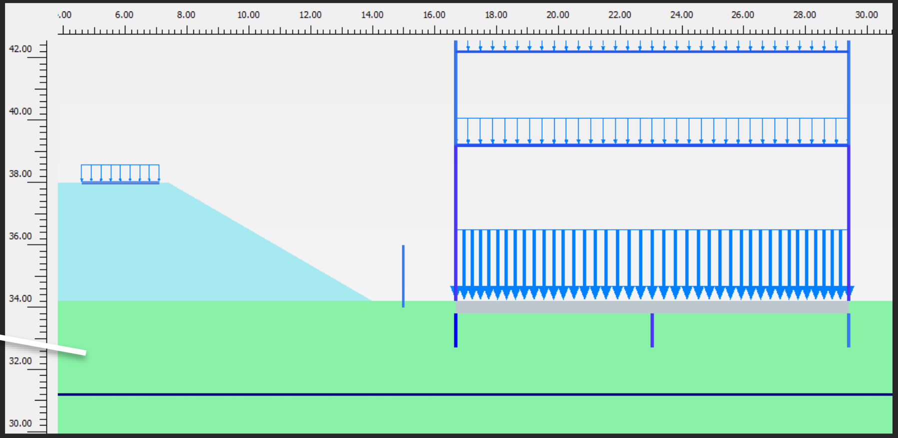
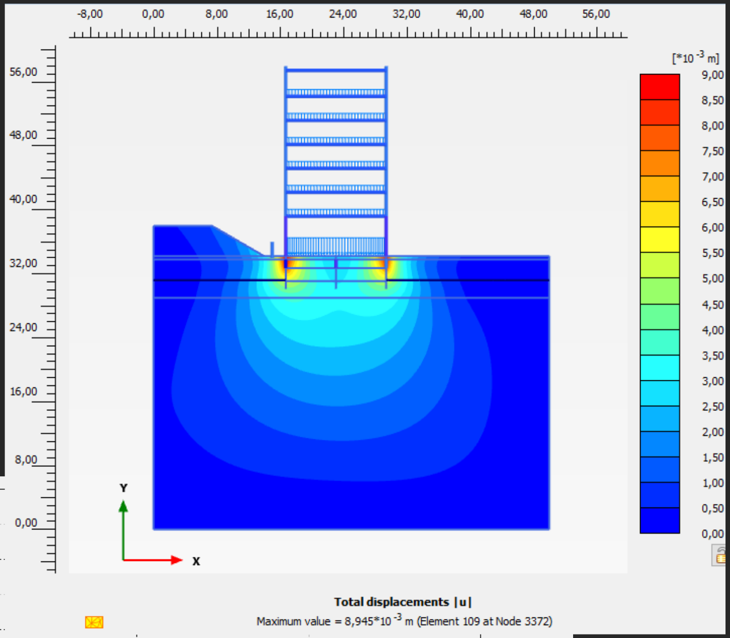
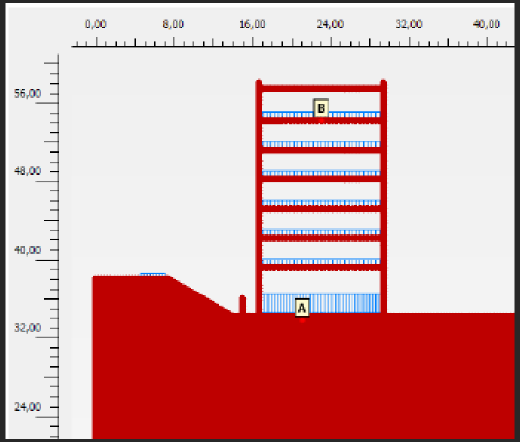
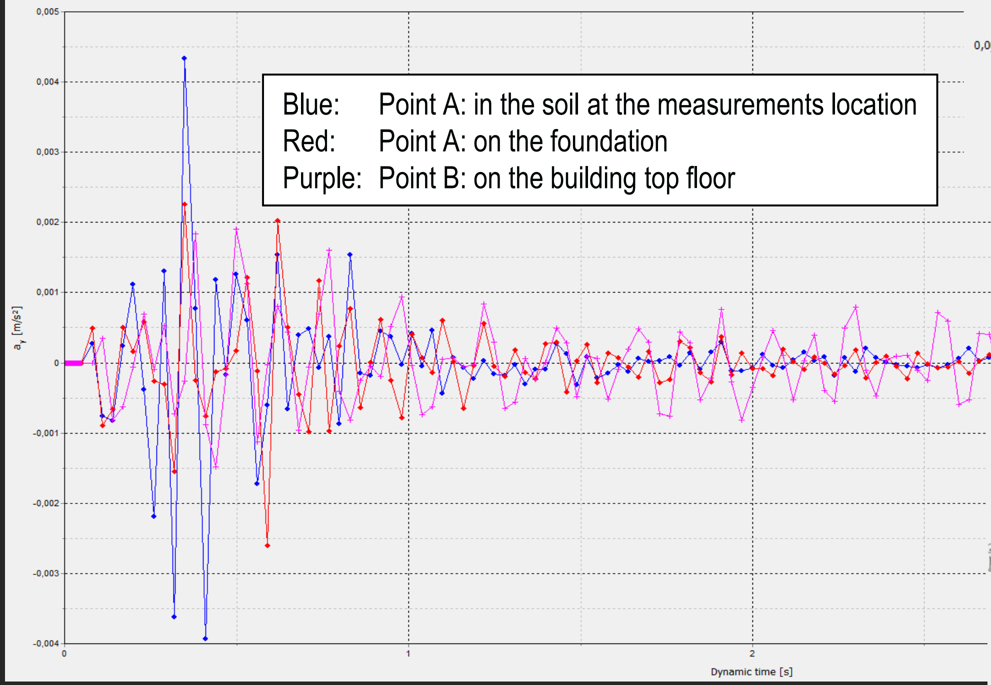
Building with strip foundations, 0.4 m ground deck and no basement – Vertical Acceleration at points A & B

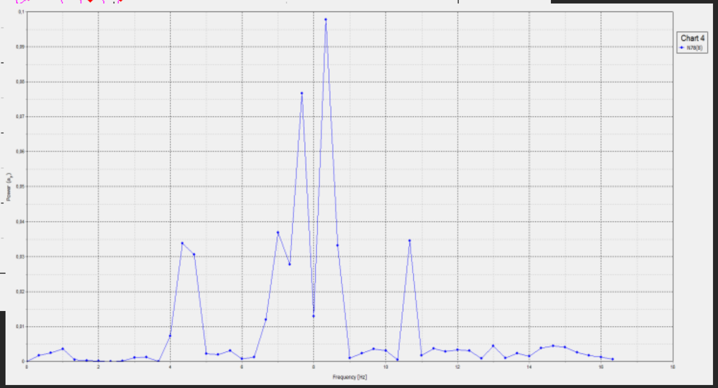




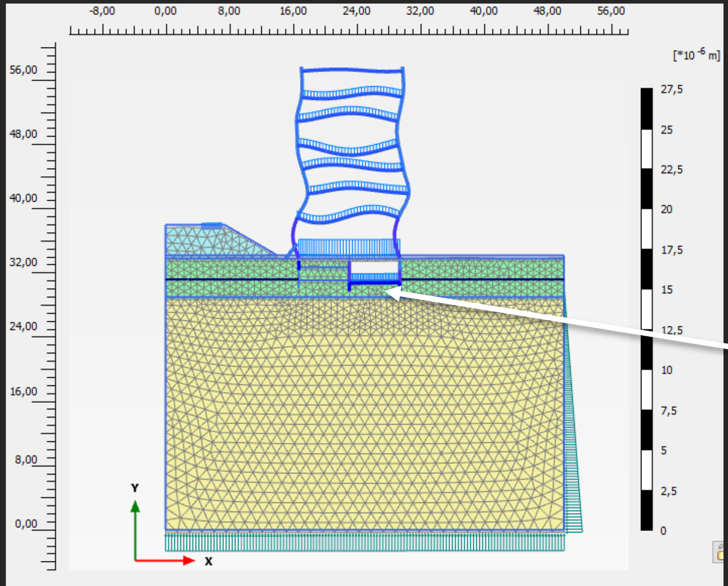




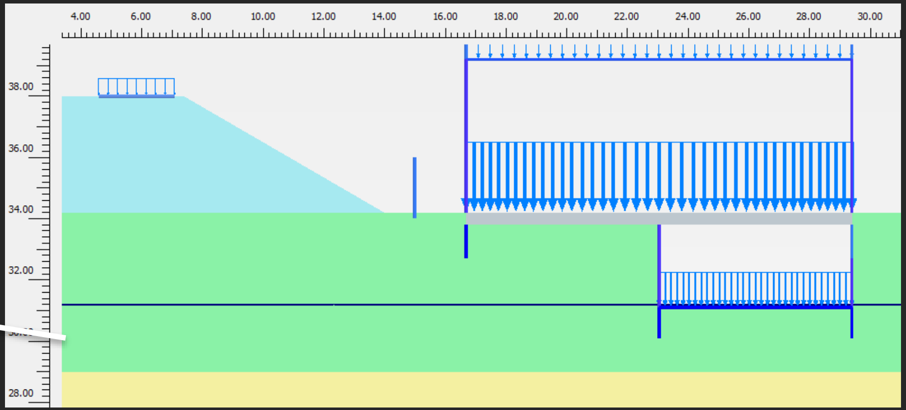


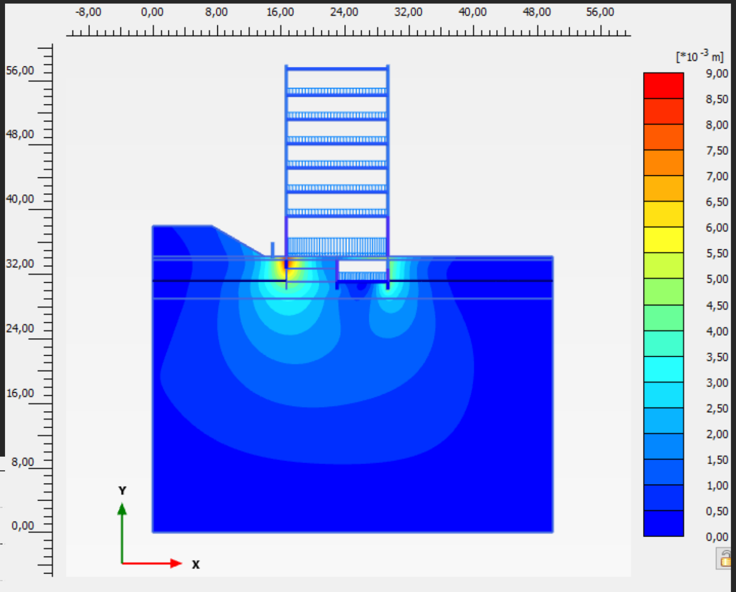


Building with strip foundations, 0.4 m ground deck and partial basement – Vertical Acceleration at points A & B

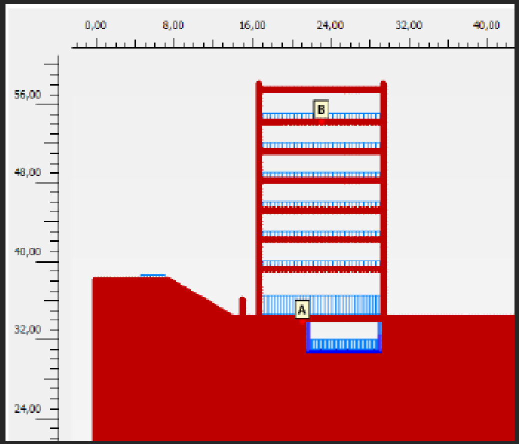


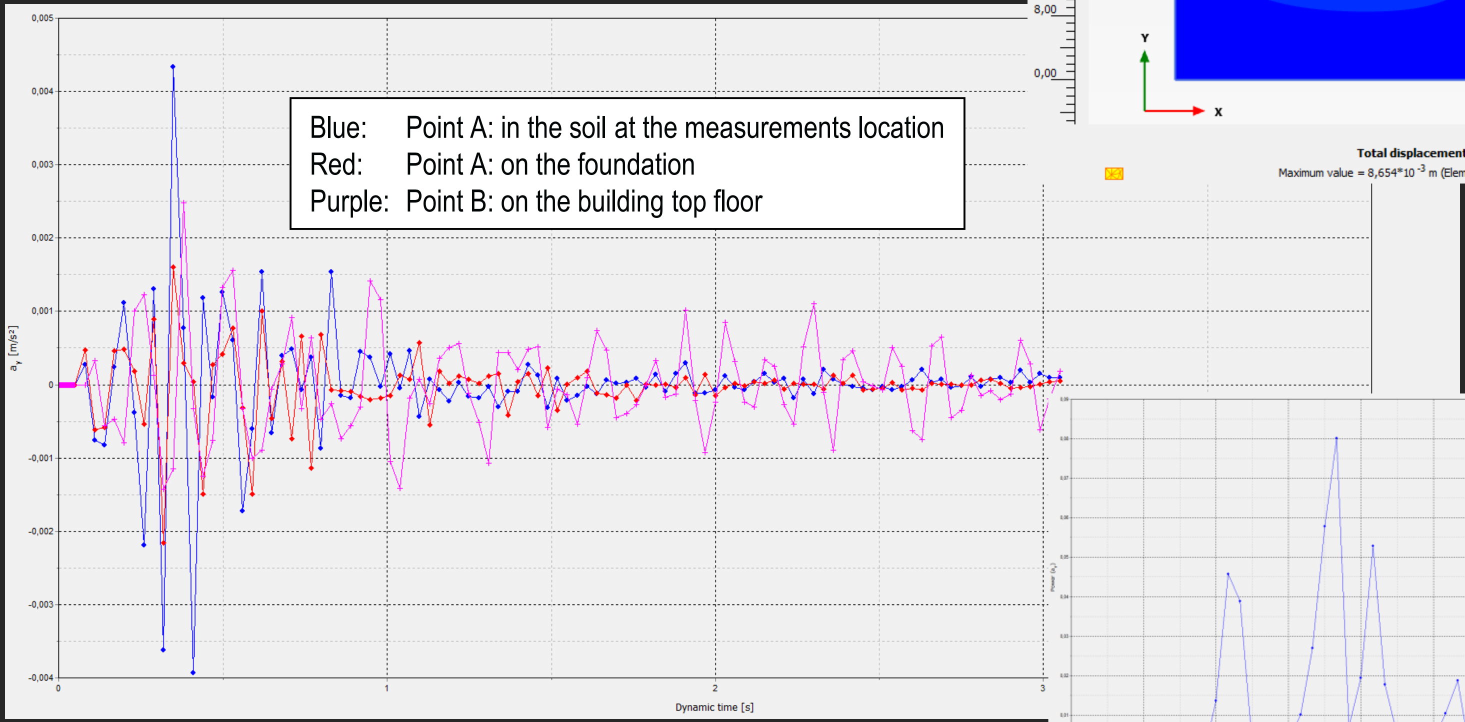
Deformed mesh |u| (scaled up $2{,}00 \cdot 10^{6}$ times)
Uniform value of $0{,}7765 \cdot 10^{-6}$ m

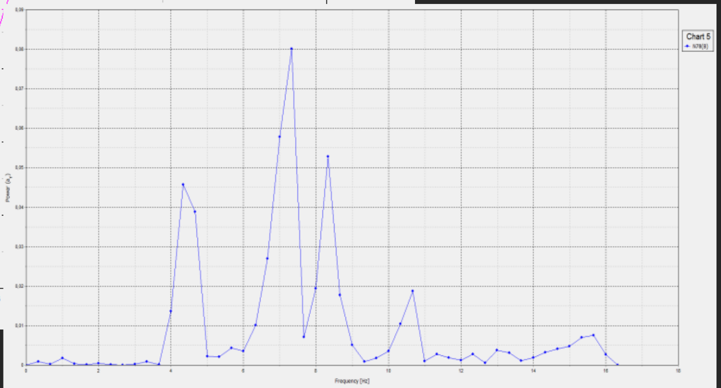




Total displacements |u|
Maximum value = $8{,}654 \cdot 10^{-3}$ m (Element 109 at Node 3372)







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Building with 1.5 m thickness plate foundation and no basement Vertical Acceleration at points A & B

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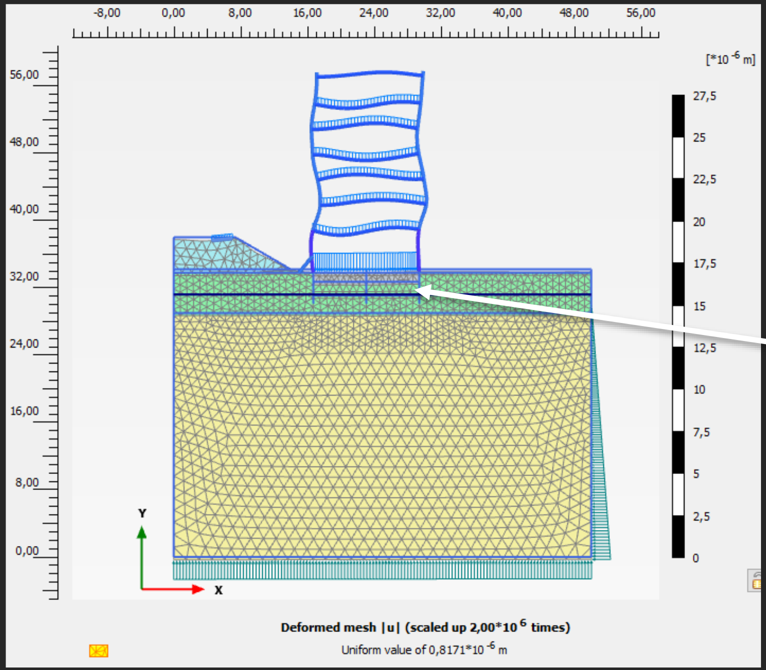

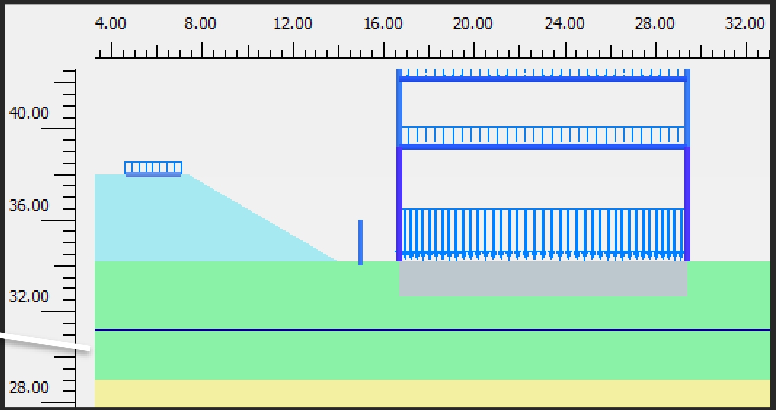

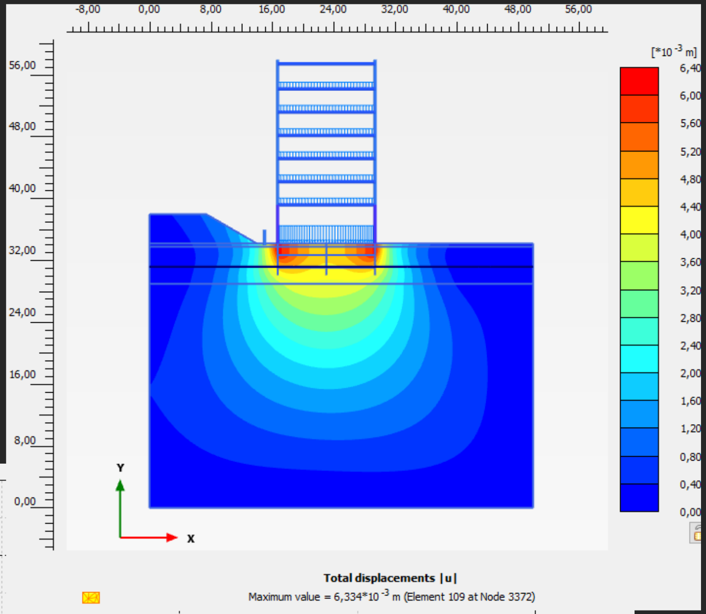

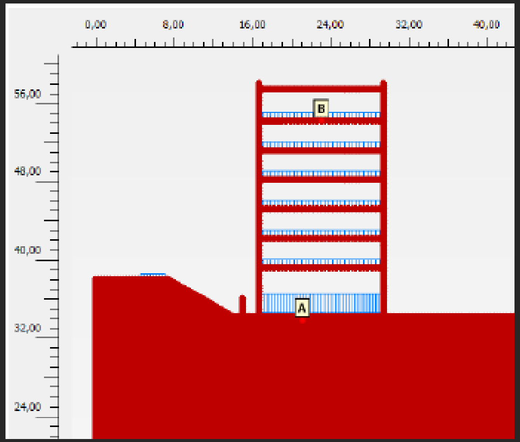

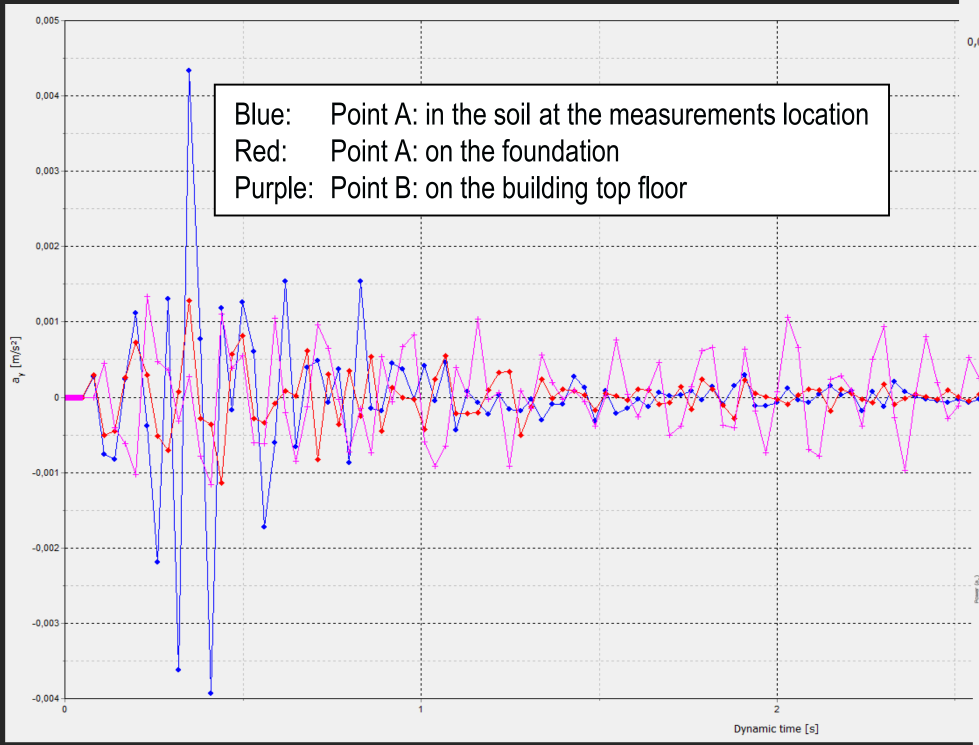

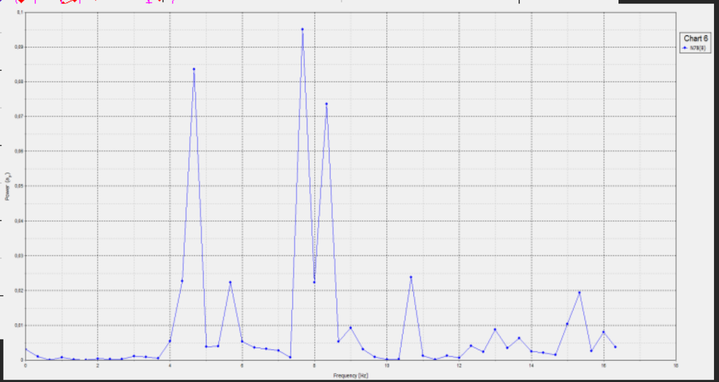

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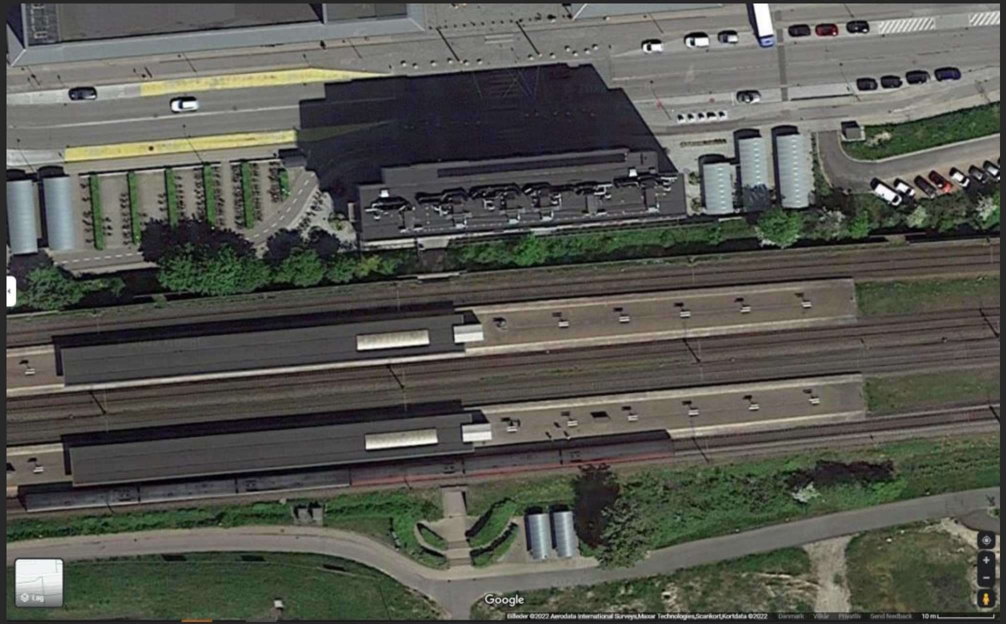
Results & Conclusions & Limitations

Calculated Vibration levels at Point B

Building Foundation Scenarios		Acceleration a_V [m/s^2]	KB-weighted vibration levels [dB re 10^{-6}]
Strip Foundation with 0,4 m ground deck	No basement	0.0019	66
	With basement	0.0025	68
Plate foundation 1,5 m thick	No basement	0,0014	63



The maximum accelerations in the vertical direction occur at a frequency of (7-9) Hz and must therefore not be reduced according to guidelines.

The generated vibration level in the building amounts to a maximum of 68 dB.

It is concluded therefore, that the building complies with the Danish Environmental Protection Agency's recommendation that the maximum vibration level must not exceed 75 dB. <u>However, the following limitations apply:</u>

- The vibration measurements carried out can deviate by ± 4-5 dB.
- The trainload is simplified to a stationary (non-moving) dynamic pulse with a dominant frequency of 10 Hz, hence, disregarding train velocity.
- 2D plane strain modeling of the railway and building is applied, while the propagation of vibrations in the ground takes place in 3D.
- There is no documented experience in converting dB vibrations measured in soil, to FE vibration modeling (where the results are calculated in form of deformations (m), velocities (m/s) and accelerations (m/s2).
- **Hence, more investigations & analyses are required and are going on.**

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Alternative Solutions – Ground Vibration Measures between the Train Station & Building – Previous Author's Works

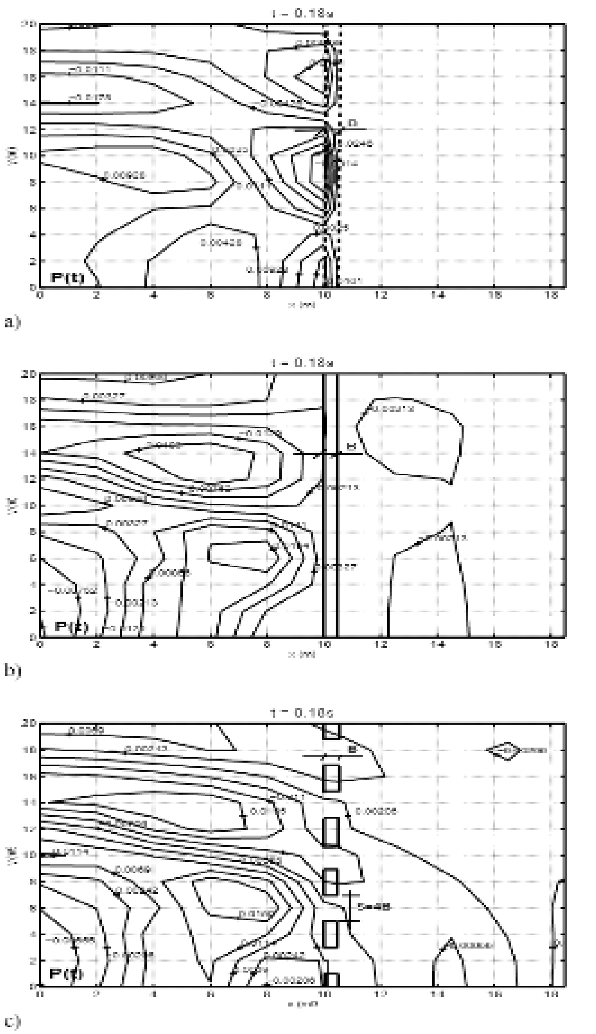

Fig. 7. Vertical acceleration at z=0m. a) Open trench b) Concrete wall c) Row of pile. R=0.83λ_S B=0.04λ_S L=1.65λ_S

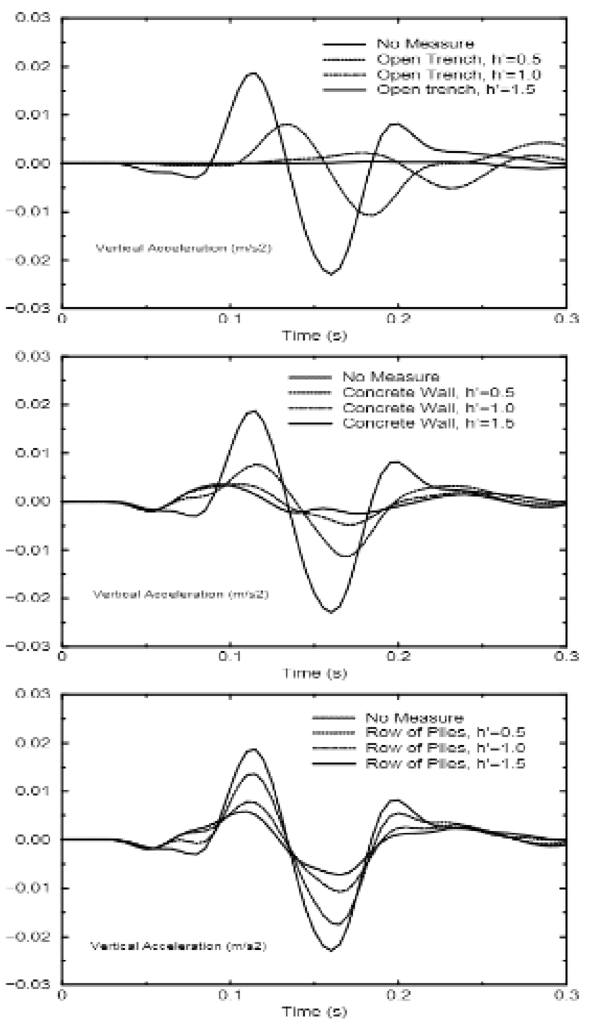

Fig. 6 Dynamic response after the measure, at x=12.5m, y=0m, z=0m. R=0.83λ_S B=0.04λ_S L=1.65λ_S

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- **Kellezi L**. (2011), 'Dynamic Behaviour of a Softer Layer Overlying Hard Soil / Bedrock and Vibration Reduction, Proc. 15th European Conf. on Soil Mech. & Geotech. Eng. ECSMGE 2011, September, Athena, Greece, page 1771-1776.
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- **Kellezi L**. & Takemiya H. (2001), 'An Effective Local Absorbing Boundary for 3D FEM Time Domain Analysis', 4th International Conf. on Recent Advances on Soil Dynamics and Earthquake Eng. March, San Diego, USA, Paper No 6.49
- **Kellezi L**. (2000), 'Transmitting Boundaries for Transient Elastic Analysis'. Journal of Soil Dynamics and Earthquake Engineering. Vol. 19, No. 7, page 533-547.

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