



People with solutions

M+P | MBBM group
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Complaints about vibration-induced noise from the underground metro line in Amsterdam

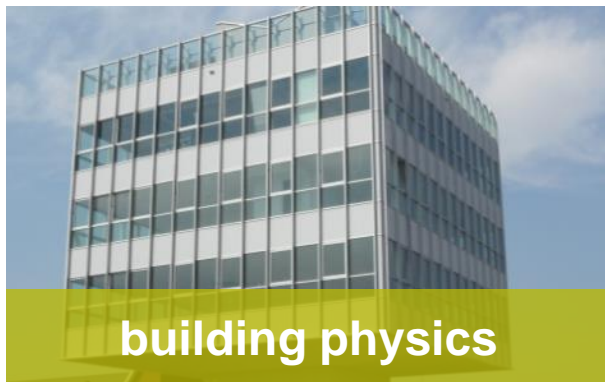
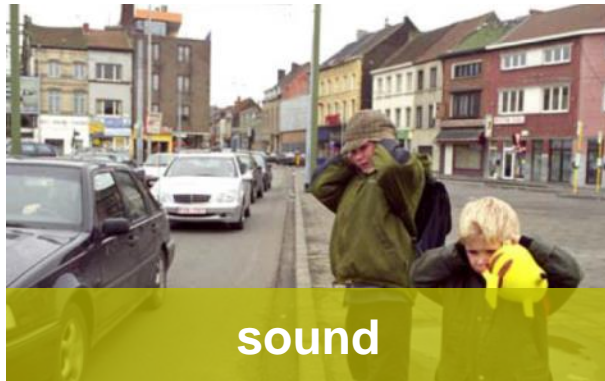
Edwin Nieuwenhuizen

Rail Technology Conferences 2014
Düsseldorf





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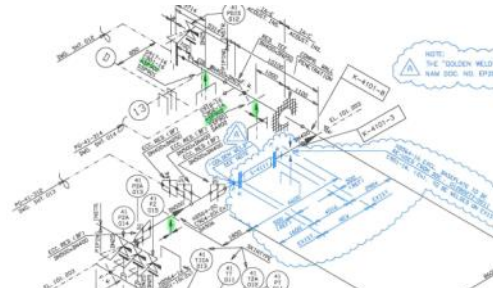
buildings



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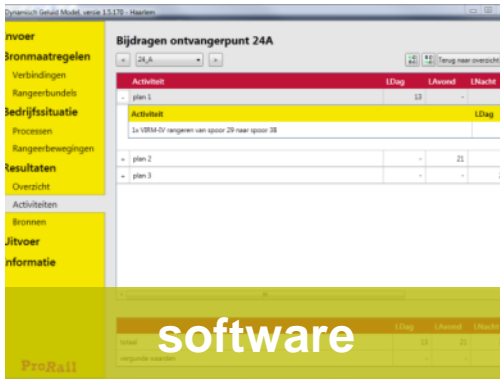
consultancy



engineering



measurement systems



software



measurements

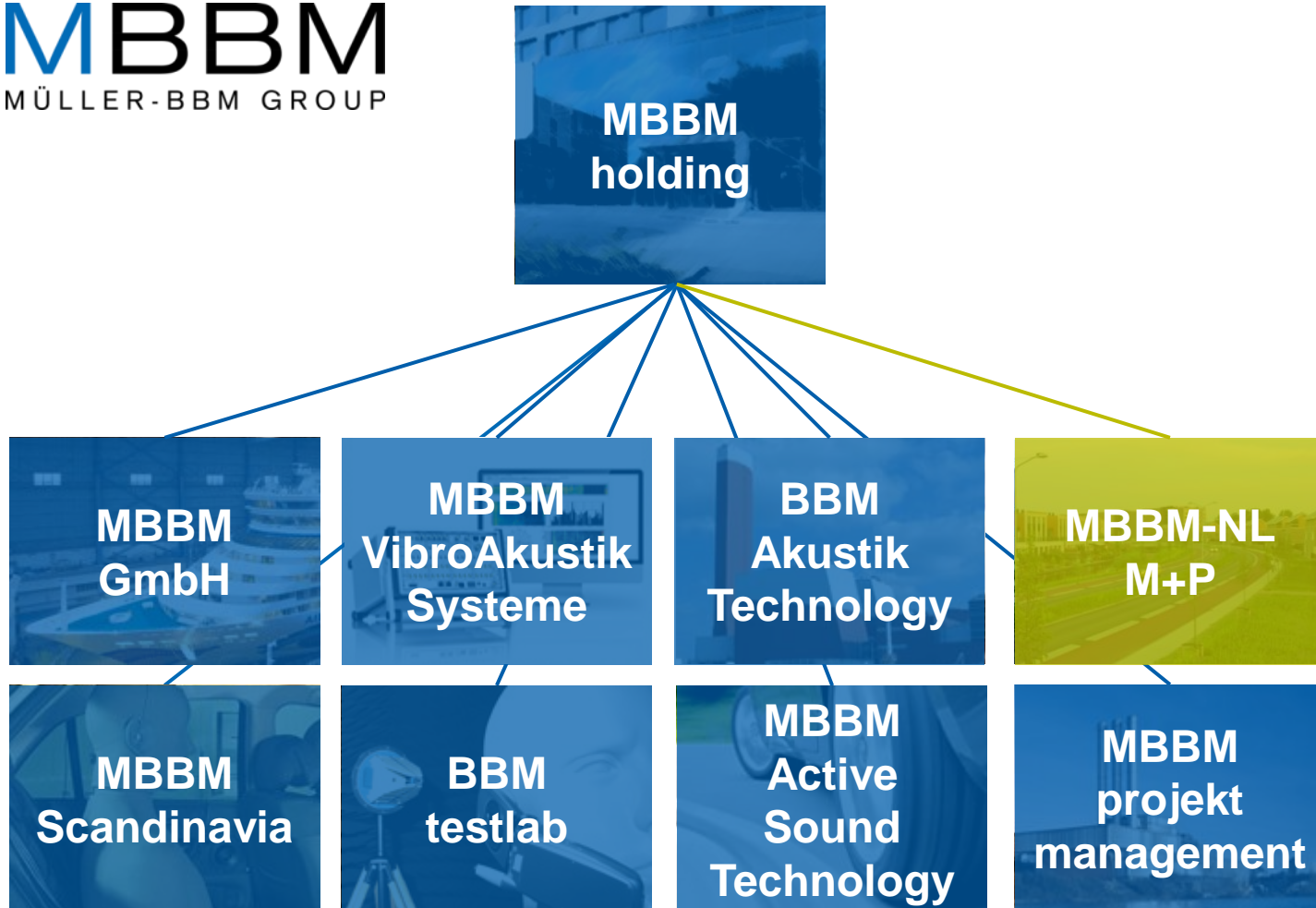


research



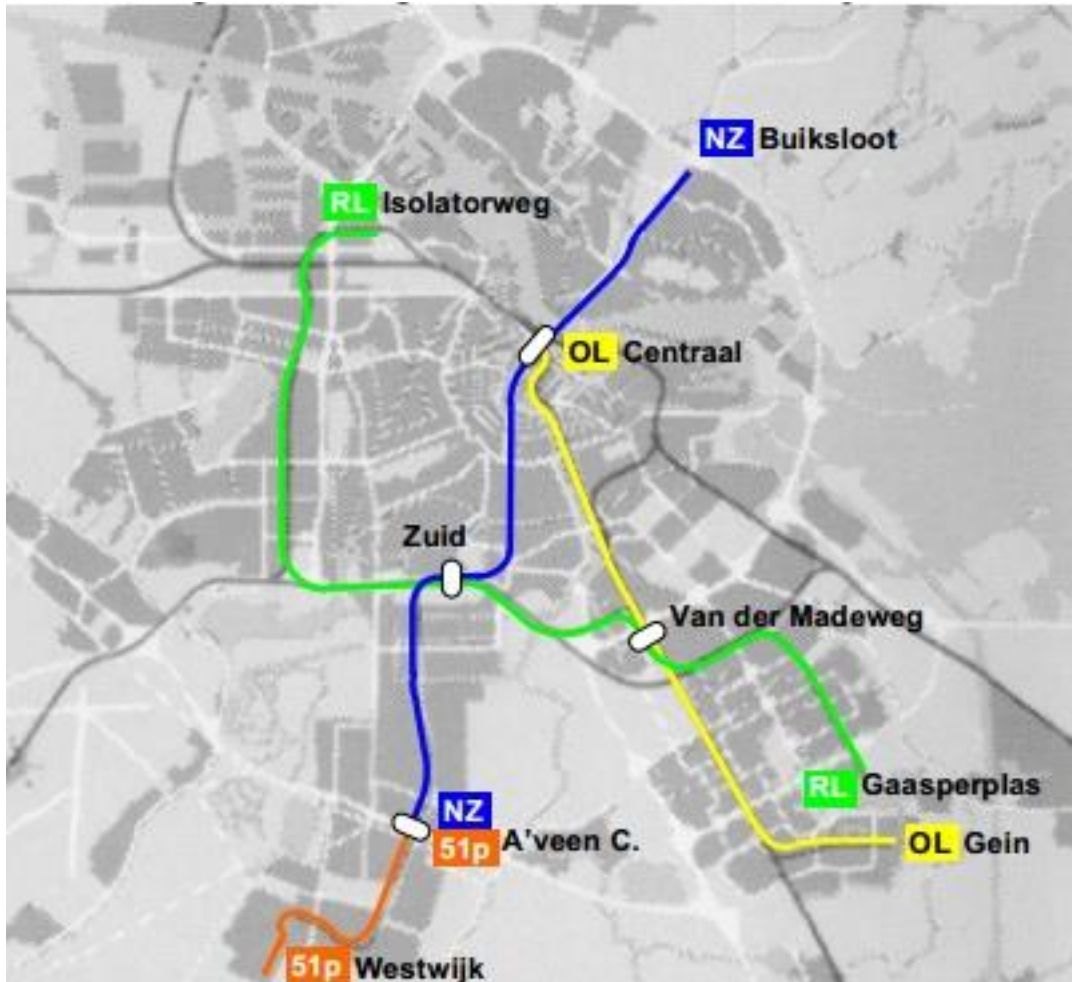
We are part of an international network of experts

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Amsterdam metro lines



underground metro lines in historic city centre

OL='East Line'
NZ='North South Line'



Metro tunnels in Amsterdam (1/2)

'East Line'

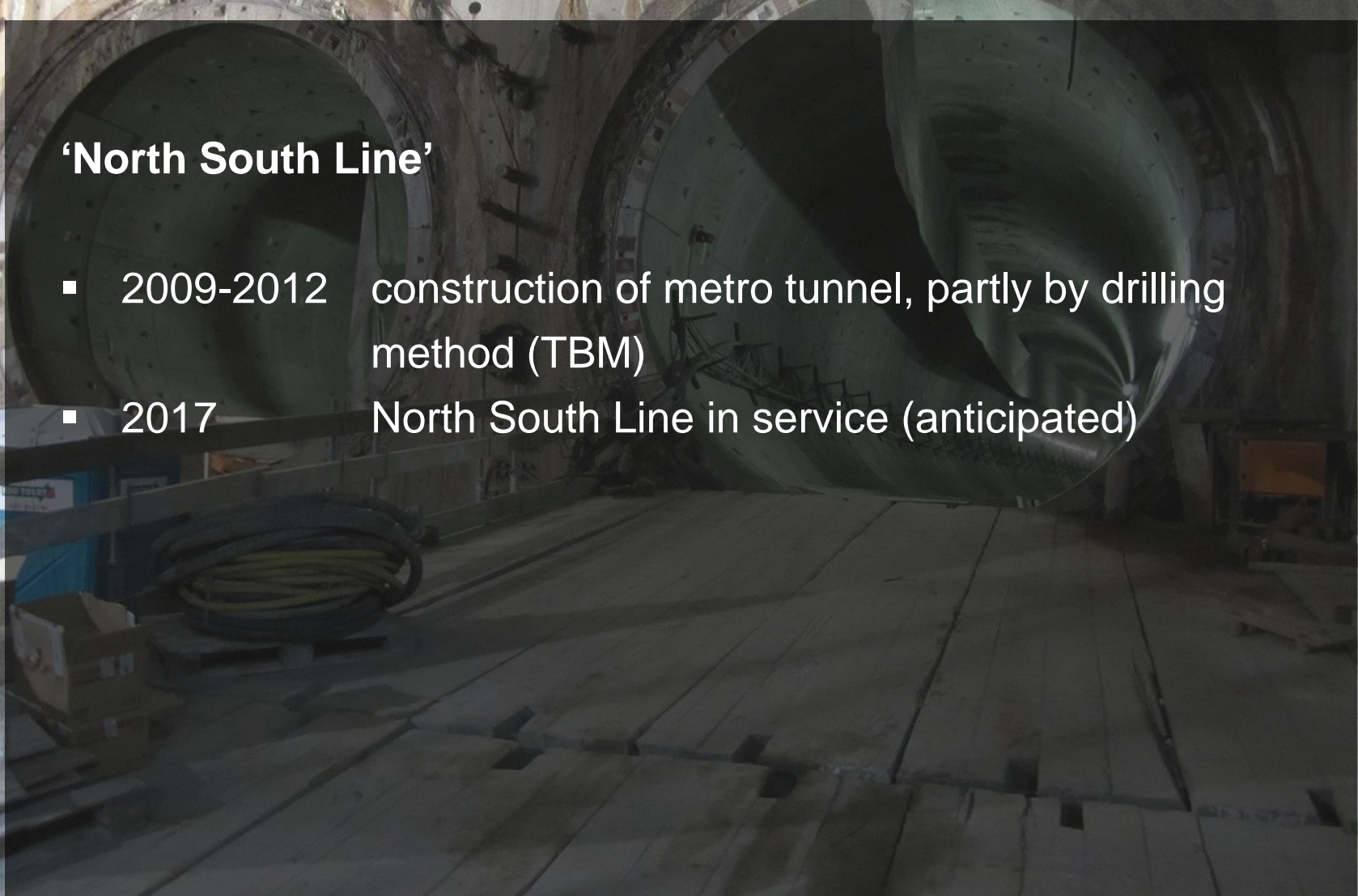
- 1975 demolition of centre district 'Nieuwmarkt'
- 1975-1980 construction of metro tunnel by sinking caisson method
- 1980 metro tunnel in service
- 1980-1985 new residences built on top of tunnel, isolator pads in building structure to prevent nuisance
- 2007-2013 complete renovation and replacement of the rail superstructure
- 2014 introduction of new rolling stock (M5)



Metro tunnels in Amsterdam (1/2)

'North South Line'

- 2009-2012 construction of metro tunnel, partly by drilling method (TBM)
- 2017 North South Line in service (anticipated)





Noise and vibration nuisance

- recent increase of noise complaints caused by the 'East Line' in district Nieuwmarkt
- very emotional response by residents
- description of nuisance is divergent
- in general: increase in noise generated by metro pass-by since 2012
- survey goal of M+P (2013): to objectify the complaints and to find the most probable cause of the increase of number of complaints
- project scope is not yet to find solutions for mitigation



Stakeholders

- disturbed residents
- several housing corporations
- GVB – metro carrier
- Dienst Metro – infrastructure manager
- other departments of Amsterdam municipality



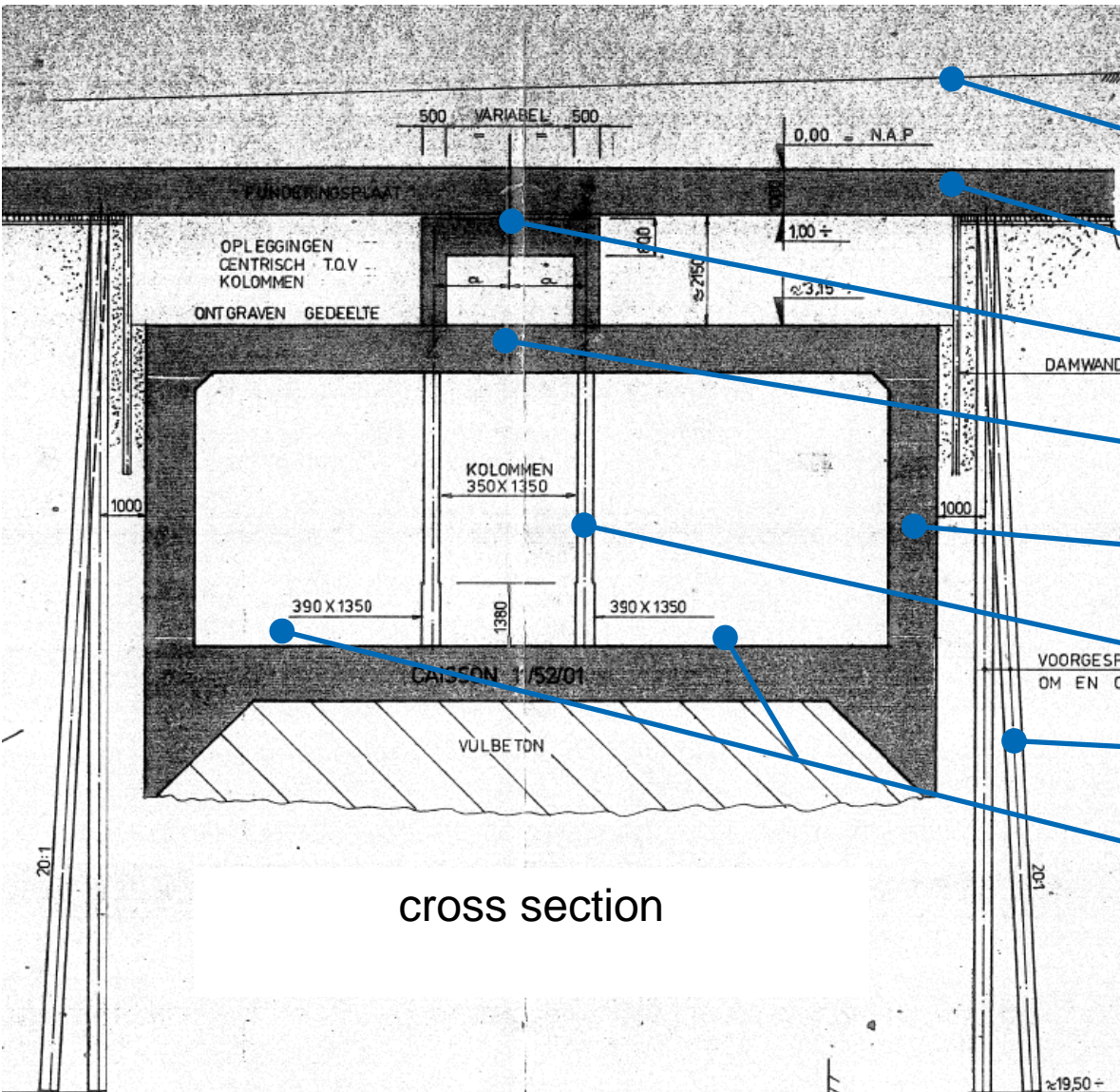
Project planning

Given: narrow time schedule and limited budget

- enumerating possible causes of increased number of complaints
- conducting measurements in June 2013:
 - simultaneous at tracks, tunnel structure, building foundation and residential spaces
- historic measurement and construction data available in December 2013
- measuring of track roughness in December 2013
- final vibration measurements anticipated in April 2014



Tunnel structure example



- ground level
- building foundation
- support beam
- caisson deck
- caisson wall
- concrete column
- concrete piles
- 2 ballasted tracks

cross section



Noise requirements 1980

requirements for residences, imposed by the Department of Building Inspection of the Amsterdam municipality

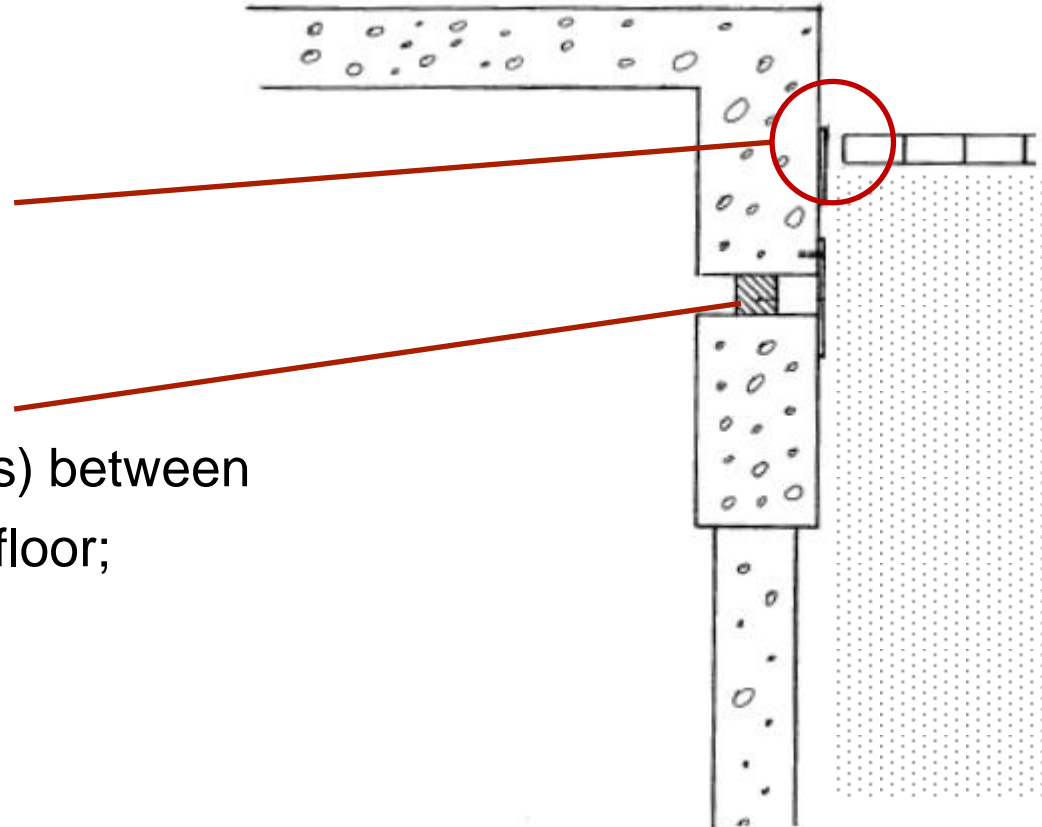
	day	evening	night
equivalent L_{eq}	35 dB(A)	30 dB(A)	20 dB(A)
peak L_{Amax}	45 dB(A)	40 dB(A)	30 dB(A)

Mitigation of vibration-induced noise

Amsterdam Pentagon building

no contact between
pavement and facades

rubber isolator pads (609 pcs) between
basement walls and ground floor;
no rigid joints (e.g. piping)





Possible causes of nuisance (1/3)

Receiver (residents)

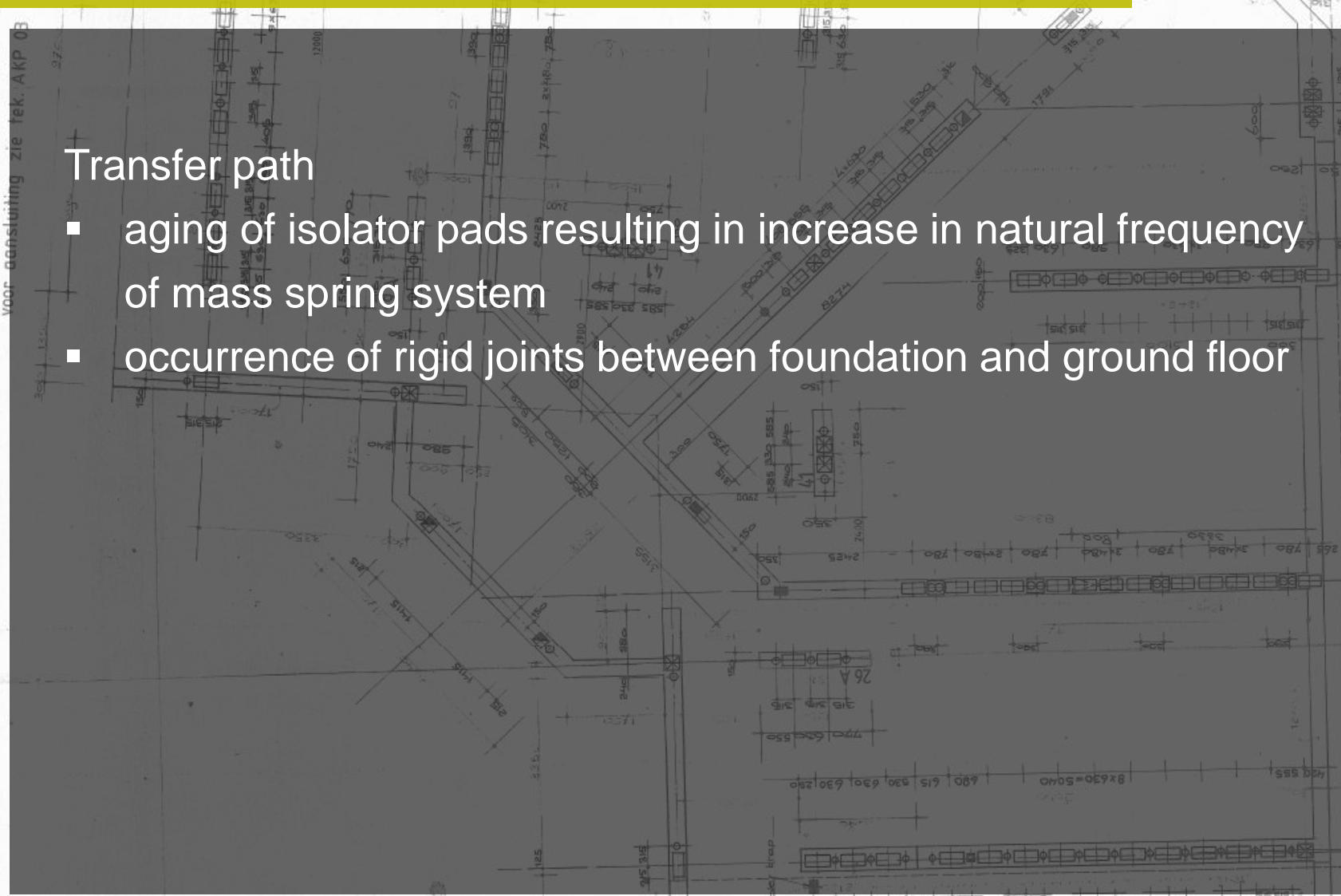
- psycho acoustic effects (negative publicity 'North South line')
 - sinking buildings along route
 - nuisance from construction noise
 - construction costs 100% over budget (€1.5 bn)



Possible causes of nuisance (2/3)

Transfer path

- aging of isolator pads resulting in increase in natural frequency of mass spring system
- occurrence of rigid joints between foundation and ground floor





Possible causes of nuisance (3/3)

At the time of renovation of track, acoustic/vibrational consequences were not considered

Source

- new provisions for tunnel safety (airborne noise)
- different behavior of new track superstructure (renovation)
- longitudinal sagging of the rail bed (renovation)
- increase of rail roughness (regular maintenance)
- increase of wheel roughness (reduced maintenance of M2/3 stock that will be replaced by M5)
- new train configuration (3 coupled carriages)



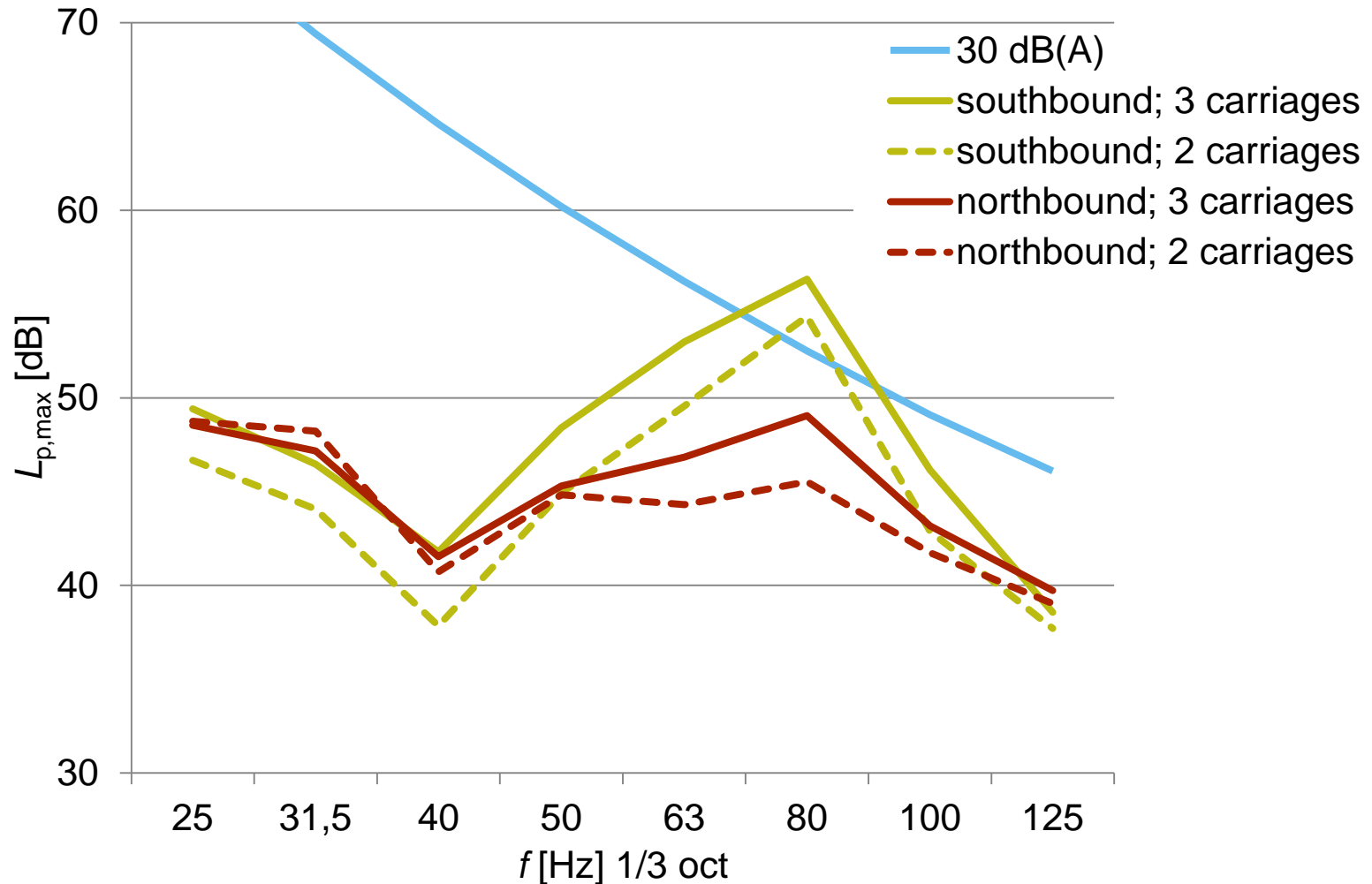
Measurements in residential space (1/2)

Amsterdam Pentagon building, 3th floor – June 2013

- L_{Amax} is higher than 30 dB(A) limit
- 80 Hz 1/3 octave band is predominant and responsible for nuisance
- pass-by on southbound track noisier than vice versa (+8 dB)
- metros with 3 carriages noisier than with 2 (+2 dB)
- wall vibration level matches noise level: no airborne transfer path



Measurements in residential space (2/2)





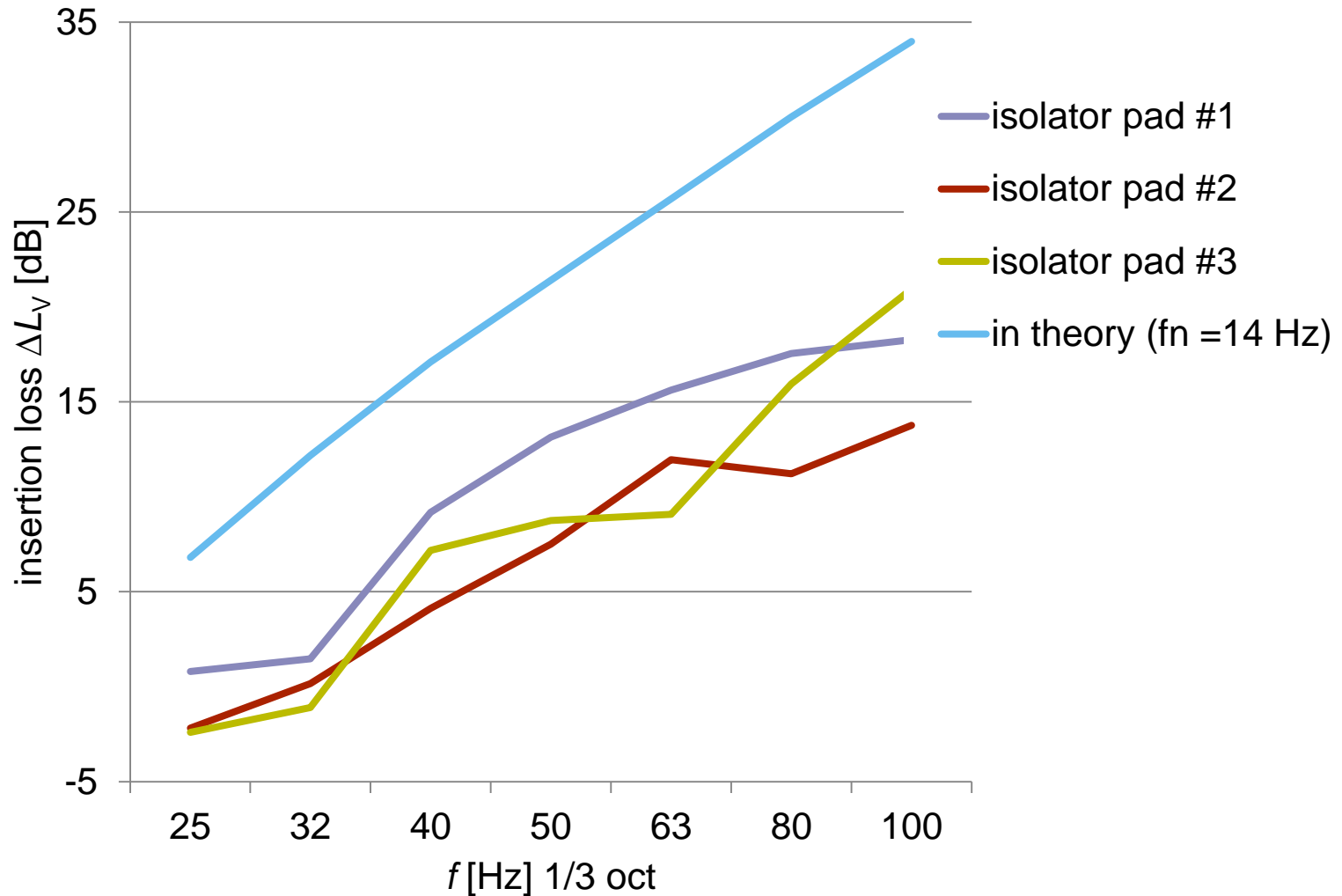
Measurements in basement (1/3)

Amsterdam Pentagon building, basement – June 2014

- quick inspection revealed possible deviations:
 - not all isolator pads are load bearing
 - flexible joints between non-bearing walls and ground floor are not visible (rigid contacts?)
 - no gap between pavement and facade
- in situ measured insertion loss of rubber pads is about 15 dB at 80 Hz
- vibration levels on ground floor highest above supposed non-bearing walls and near facades (reveals a vibration bypass)



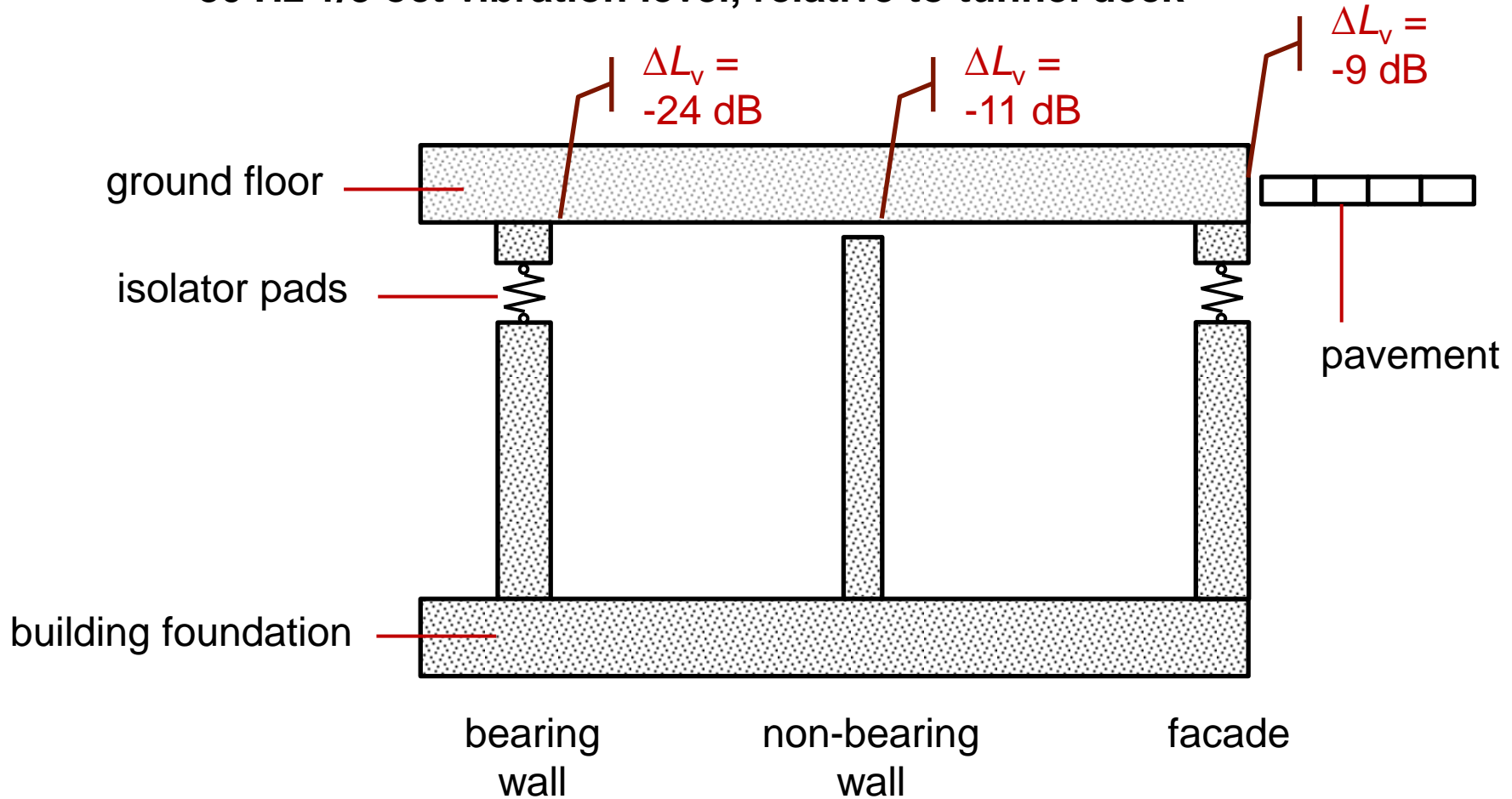
Measurements in basement (2/3)





Measurements in basement (3/3)

80 Hz 1/3 oct vibration level, relative to tunnel deck





Measurements on tunnel wall

L_v [dB re 50 10^{-8} ms^{-1}]
western tunnel wall, curved track
horizontal direction

Date	Caisson nr	South-bound	North-bound
21-7-1980	02.08	60	56
1-3-1983	02.08	68	60
24-8-1985	52.05	68	63
24-8-1985	52.07	64	65
27-6-2013	km 1.100	66	58

- apparently no significant increase in vibration level since the 80's
- but source-related causes may not be rejected yet:
 - not exact same measurement position
 - large scatter (± 4 dB)
 - relatively limited number of pass-bys



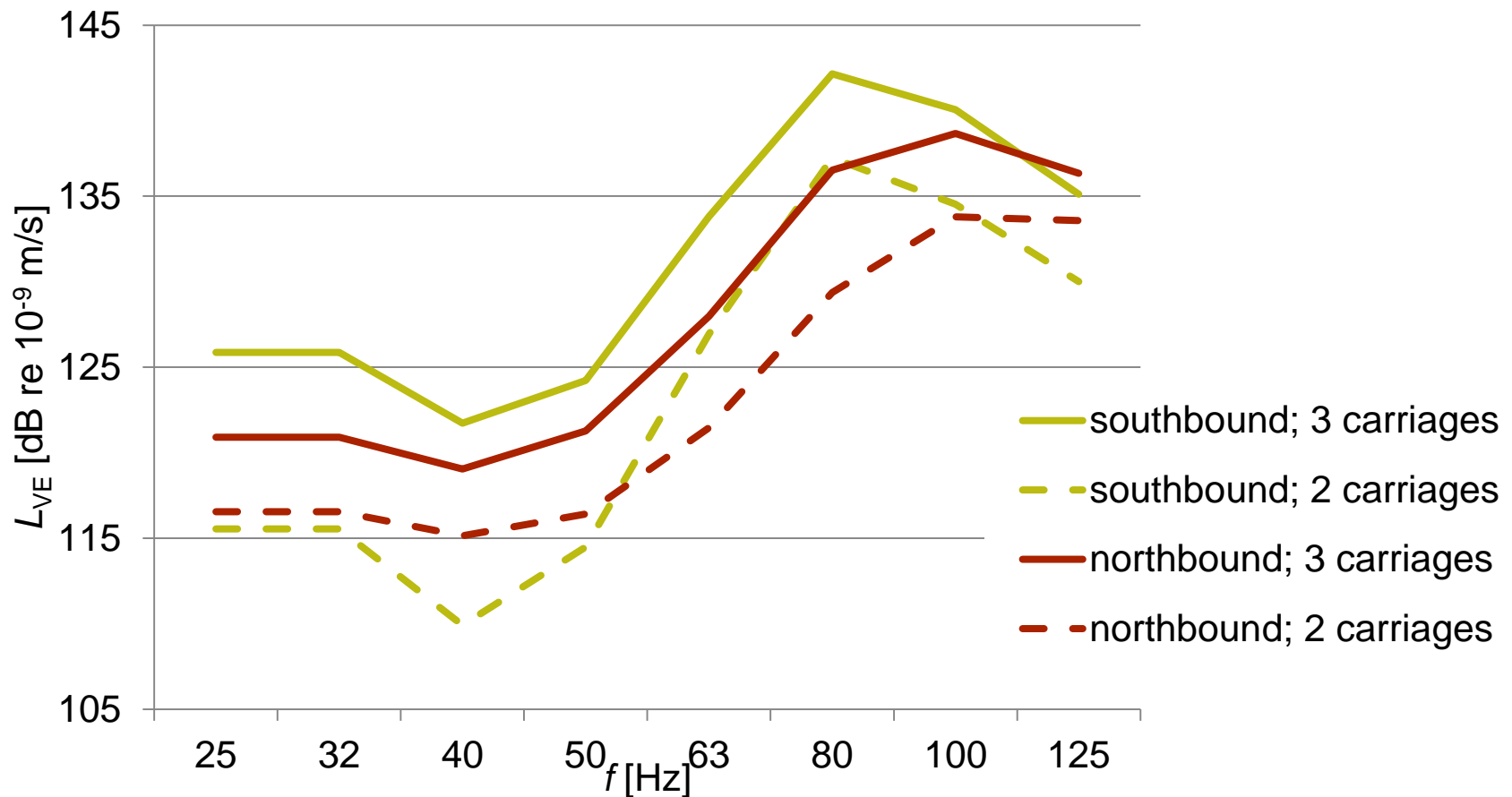
Measurement on rail foot (1/3)

- metros with 3 carriages cause higher vibration levels than with 2 carriages
- average vibration level of southbound track is higher than northbound
- metros change direction at CS: wheel roughness is probably not the cause
- vertical Track Decay Rates of tracks seem normal



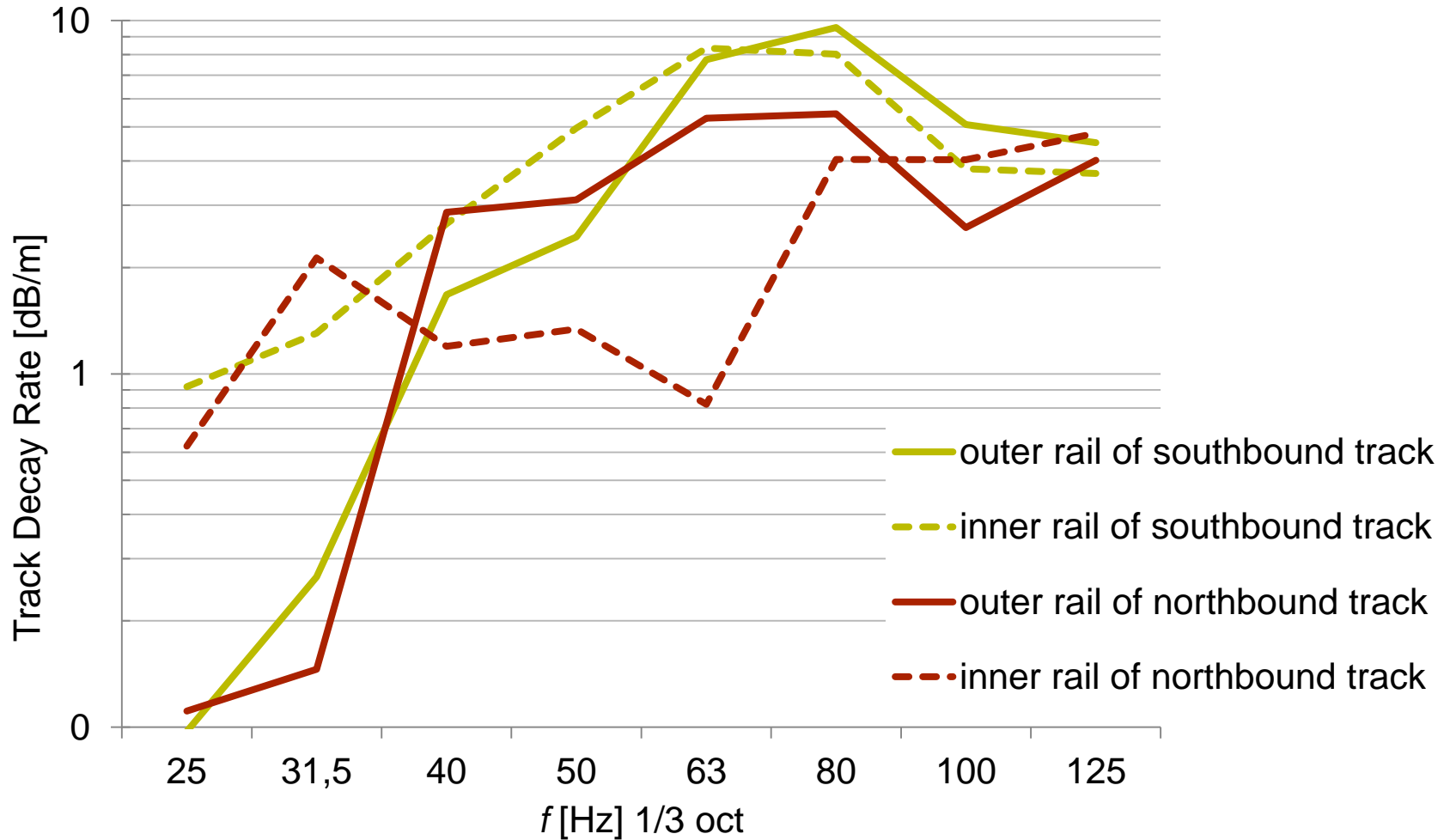
Measurement on rail foot (2/3)

average of inner and outer rail





Measurement on rail foot (3/3)





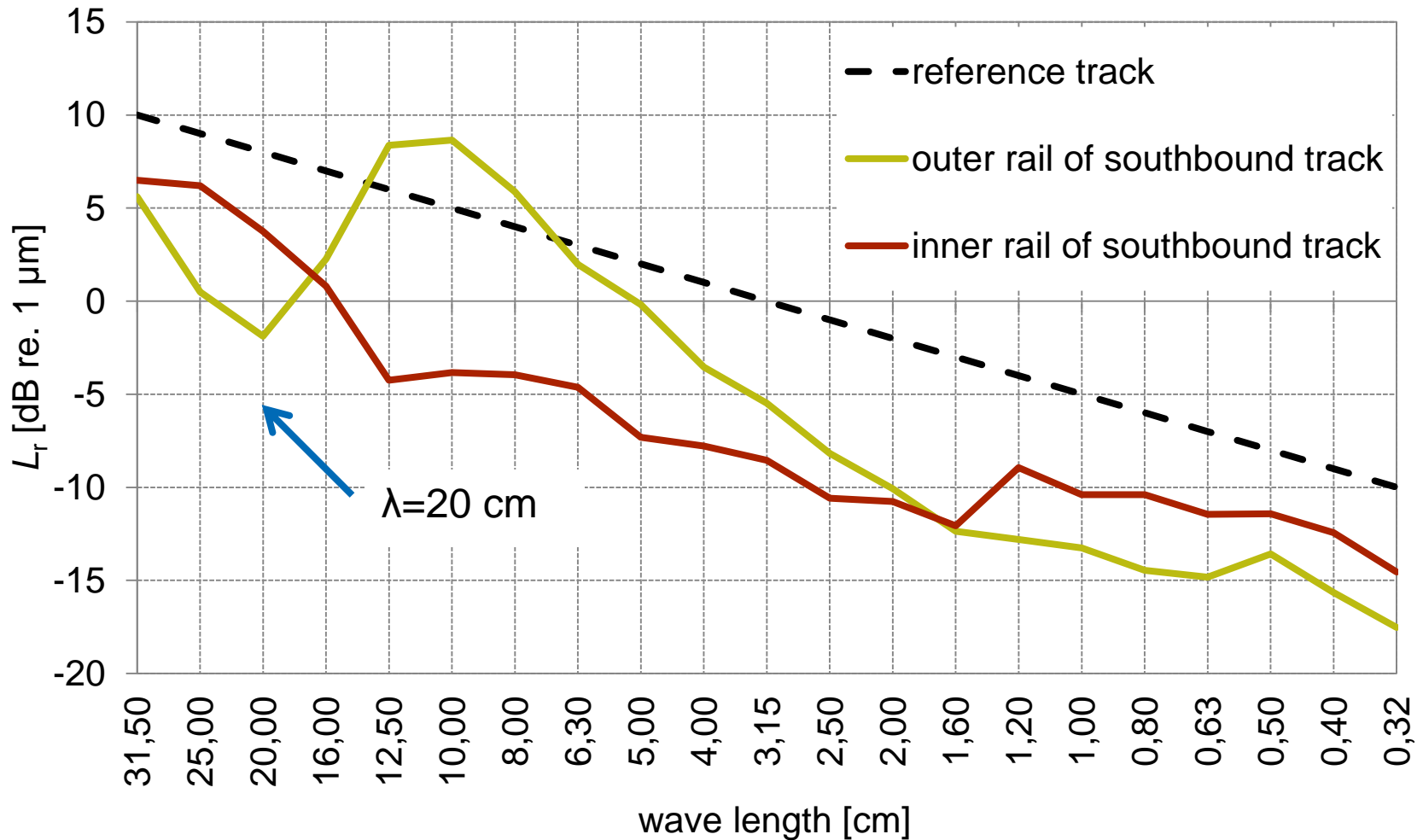
Rail roughness measurements (1/2)

Measurements done prior to rail head grinding

- 80 Hz at 60 km/h, thus $\lambda=20$ cm
- no peak at 20 cm that explains noise at 80 Hz
- no decrease in complaints after rail head grinding (Jan 2014)
- rail roughness is probably not the cause of nuisance



Rail roughness measurements (2/2)





Conclusions

- metro pass-by noise level in residence is higher than requirements of 1980
- bypass of vibration isolators pads most probable cause of nuisance, possibly caused by resettling of building and/or street repaving
- it is unlikely that the cause is source-related, but this needs to be verified by final measurements, anticipated in April 2014