NGV 2022
5th Nordic Ground Vibration Day
24 October 2022 • Aarhus • Denmark

Building damage due to vibration from rock blasting – instrumented field test in Norway

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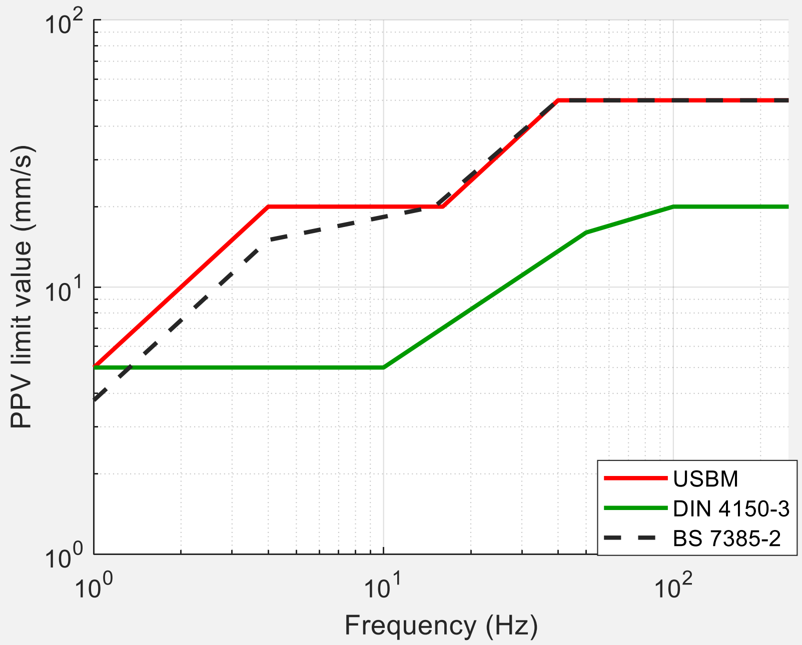
Frequency dependence in blast vibration standards

- Starting point: low frequencies are more harmful to buildings than high frequencies
- The effect of the vibrations is amplified if the frequency is close to one of the structure's natural frequencies
- For ordinary residential buildings, the natural frequency of the foundation is in the range 5 - 15 Hz
- Frequency dependence are taken into account in various ways in standards

Frequency dependent limit values

- Used in German, British and American Standards
- Frequency has to be determined
- May vary over the time series
- Results may depend on the method used to determine frequency

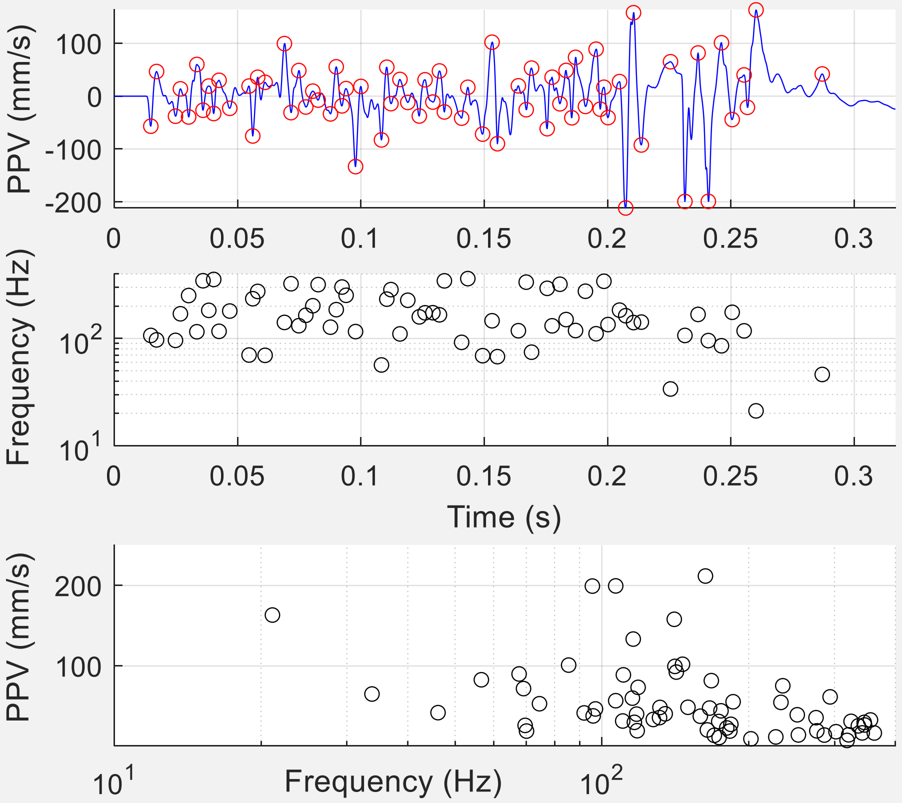


Limit values depend on factors assumed to affect the frequency

- Used in Norwegian and Swedish Standards
- Simplifications based on the following assumptions:
- Frequency decreases with distance
- Frequency is low on soft soil and high on rock
- No need to determine the vibration frequency
- Unclear how well the factors reflects the frequency and damage potential
- Does not take into account blast design and charge size

The vibration frequency problem

- Frequency varies during the blast
- Different methods to determine dominant frequency gives different results
- Distinct difference between methods focusing on the highest peak (e.g. zero crossing) and methods using the entire time series (e.g. FFT)
- Can a frequency filter replace frequency dependent limit values?



NS 8141 - Norwegian blast vibration standard

- PPV in vertical direction on building walls close to foundation.
- Limit value depends on ground condition, building type, foundation, building material, distance and vibration source.
- Varies from about 3 mm/s for a vibration-sensitive building on soft soil, to about 140 mm/s for a massive reinforced concrete structure.
- Contains a good safety margin to where damages can occur. How large?
- Blast tests to get more information about safety margins and frequency content

Spulsåsen quarry in Våler

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2018 Test buildings on rock

- 250 mm lightweight construction blocks (LECA), plastered outer surface.
- 200 mm cast-in-place concrete (no reinforcement)
- On 0.5 m compacted gravel on rock.
- Dimensions: 5 x 2 x 2.4 m.
- Door opening and one window opening
- Joists with crushed rock simulates mass of a detached house on top.

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2020 Test building on filling

- Same location as in 2018
- 250 mm LECA blocks
- Building on a 4 m filling of materials from the quarry
- Dimensions 7 x 3 x 2.4 m

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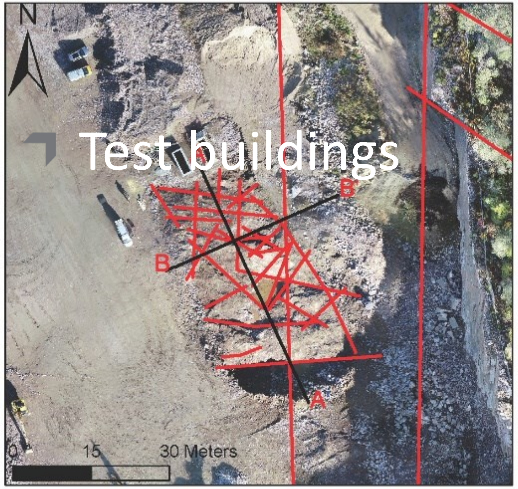
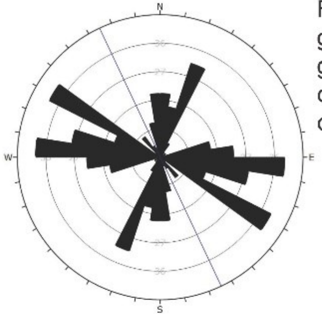
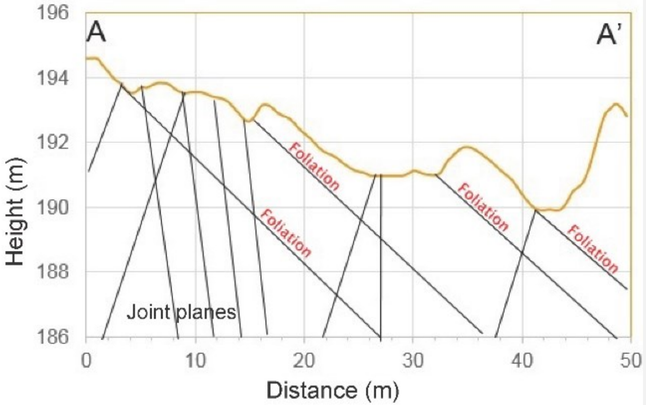
Geology of test site

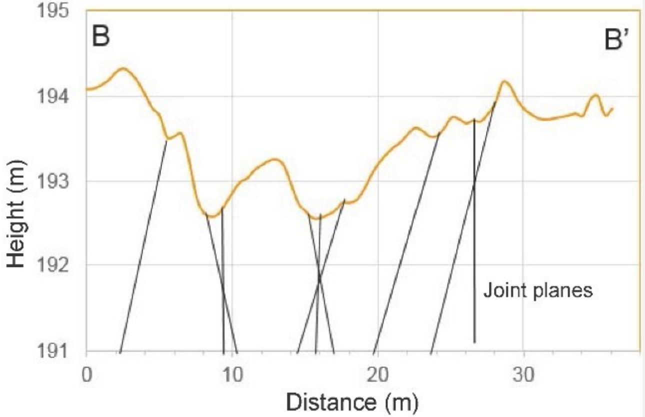
Foliations from
blast area to the buildings





Fine-to-medium-grained red granitic gneiss containing lenses of amphibolite





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Inner wall with tiles

- Cracks in tiles are a common reason for complaints
- One inner wall of the Leca buildings were covered with tiles

Limit values according to NS 8141

	First blast test Leca and concrete building		Second blast test Leca building	
	Initial value (mm/s)	20	Initial value (mm/s)	20
Ground condition	Thin compacted layer over rock	2.5	Filling with compacted material	1.8
Building category	Ordinary residential	1	Ordinary residential	1
Type of foundation	On thin compacted layer over rock	1	Strip footing	0.7
Building material	Leca blocks/ Concrete without reinforcement	1	Leca blocks	1
Distance	30 - 7 m	1	48 - 9 m	0.6-0.9
Source	Blasting	1	Blasting	1
Limit value		**50**		**16-23**

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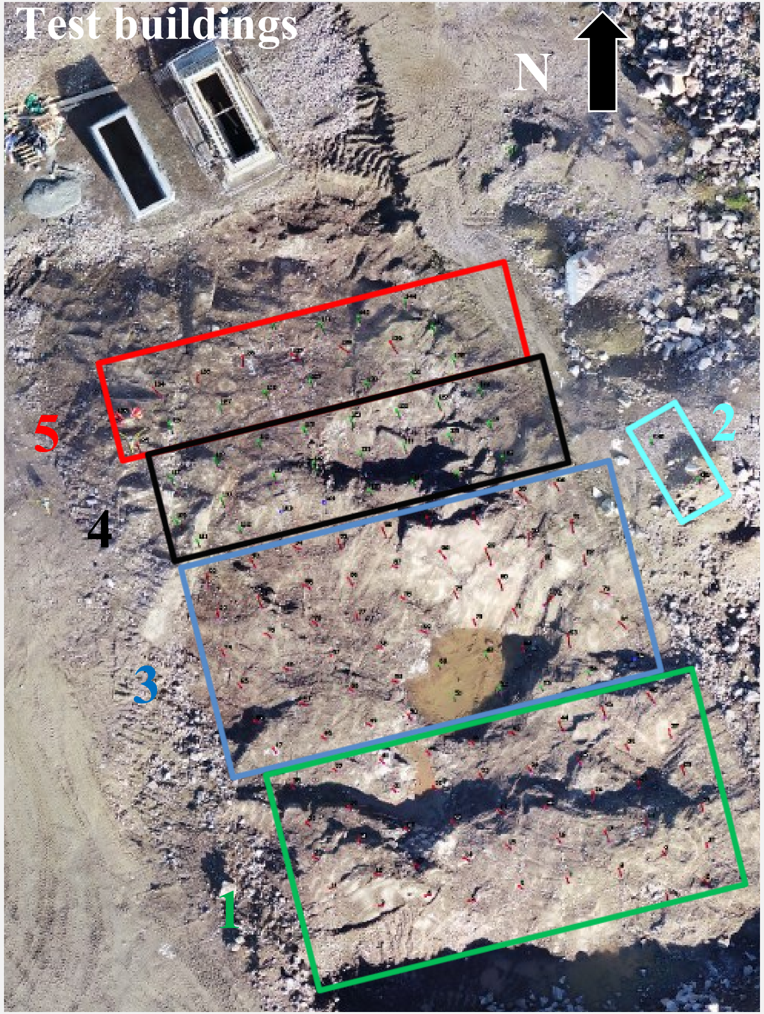

Blast design

- Designed to give increased vibration load on the buildings (decreased distance and increased charge per delay).
- 9 blast rounds with all together 363 charges holes.
- Total amount of explosives in each blast round 6.5 - 1485 kg
- Max charge per delay 2 – 48 kg.
- Distance blast - buildings 48 - 7 m

Emulex and elektronic detonator

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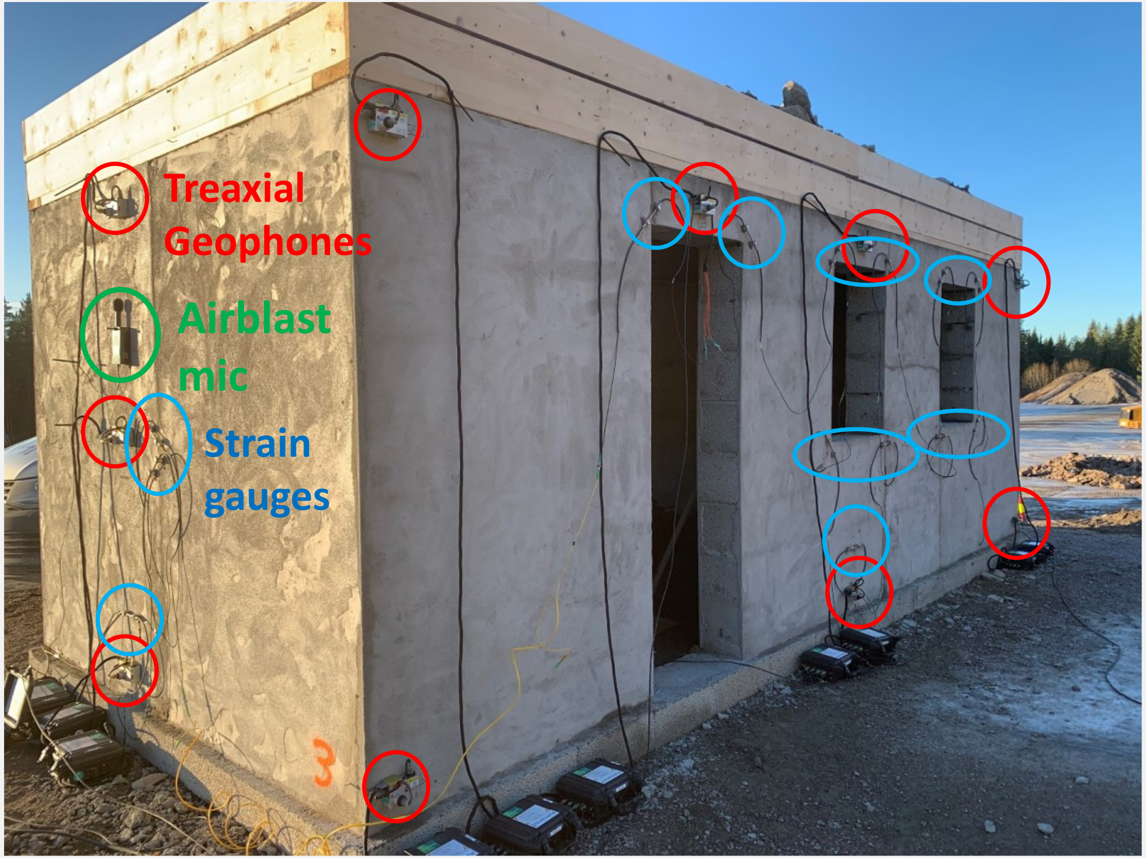
Measurement system

- AVATrace M80 measurement system for geophones and air blast microphones. 6000 Hz sampling frequency
- Each three-axial sensor was connected to one logger.
- A geophone in front of each building was used as trigger. Signal was splitted and connected to all monitors to synchronize.
- Strain measurements with a fiber optic system from Micron Optics, os3510, with 1000 Hz sampling frequency.
- Fiber Bragg Grating Sensors with 110 mm gauge length attached via rigid brackets bolted to the structures.

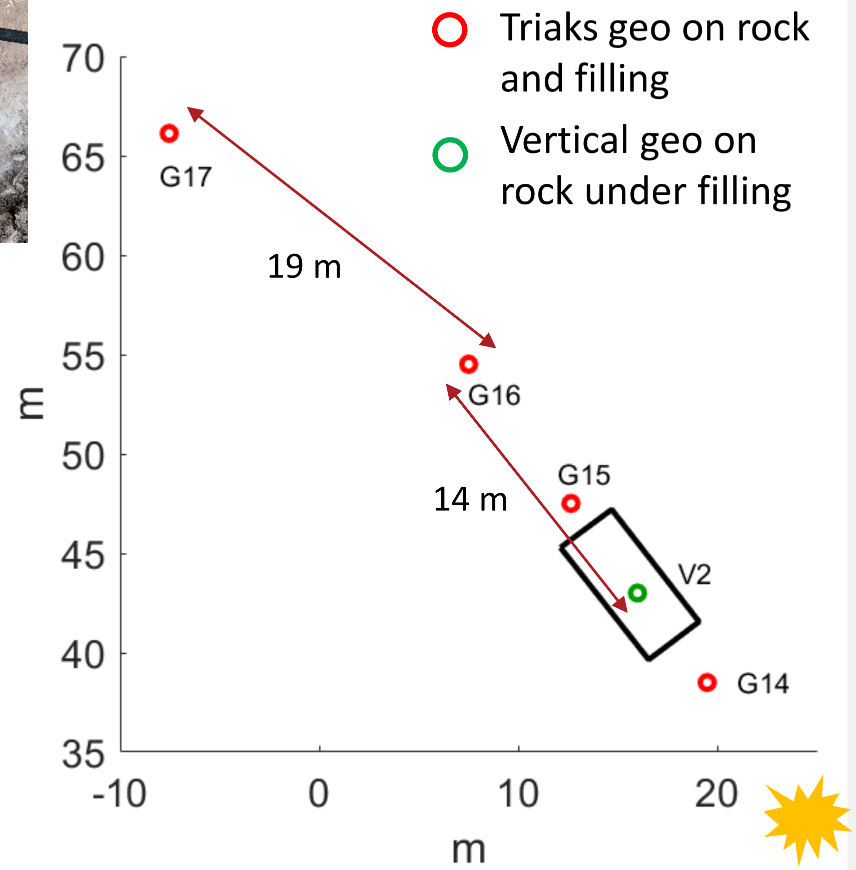
Instrumentation

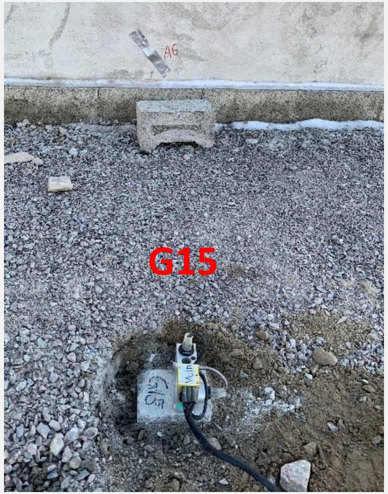


Treaxial geophones

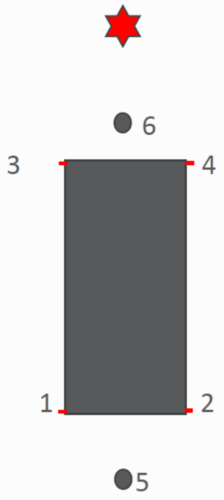
Fiber bragg grating strain sensors

Geophones on ground





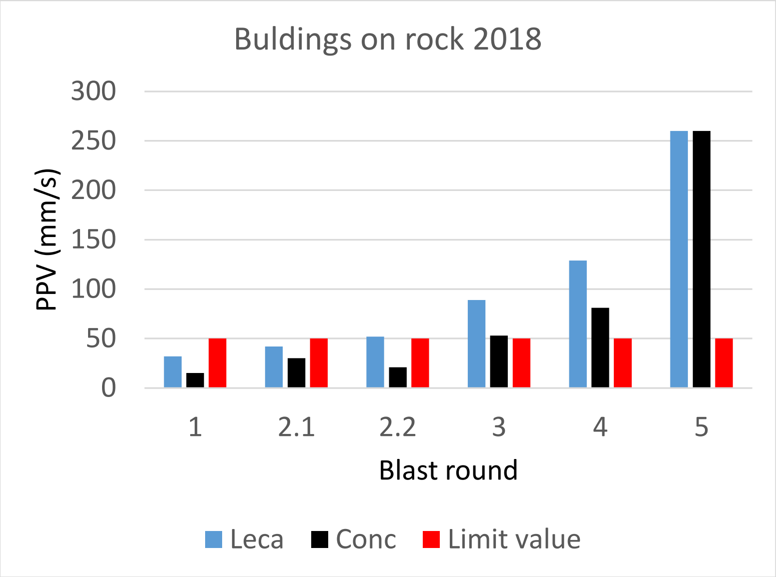
Setlements measured between each blast

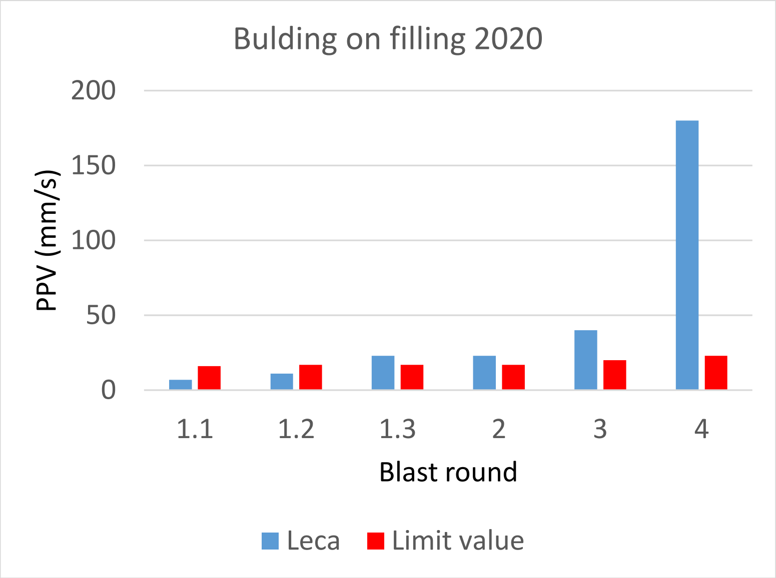


Endring fra utgangshøyde. ÷ er setning				
	Avlesning etter salve			
Bolt	**1**	**÷ 2**	**÷ 3**	**4**
1	÷ 2	÷ 1	÷ 1	÷ 2
2	÷ 2	÷ 2	÷ 2	÷ 2
3	÷ 2	÷ 2	÷ 3	÷ 4
4	÷ 3	÷ 2	÷ 3	÷ 4
5	÷ 2	÷ 1	÷ 1	÷ 1
6	÷ 12	÷ 10	÷ 12	÷ 10

Blast 4 - 2020

Vibrations





Limit values were well exceeded. No damages could be seen

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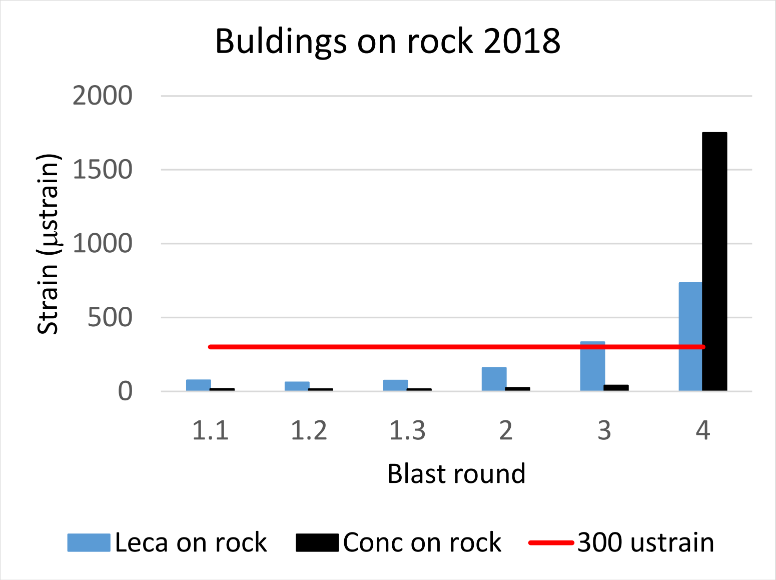
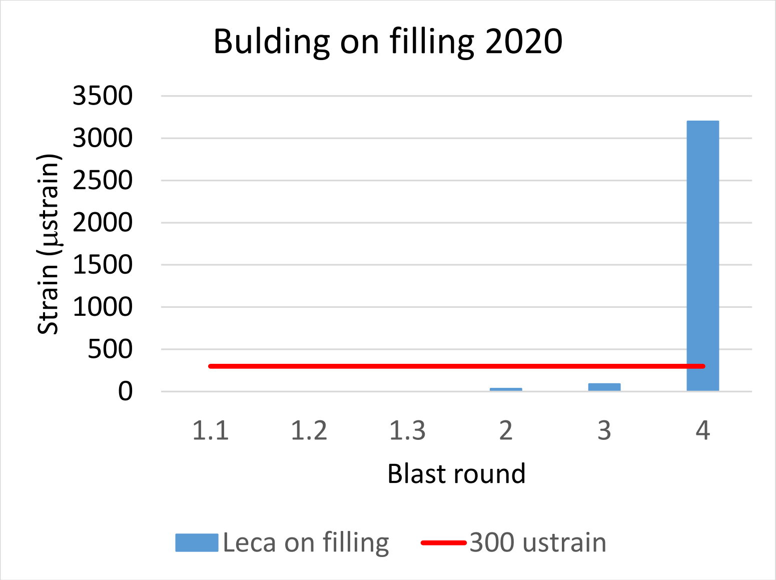
Strain





- Clearly visible dynamic strain also for low blast loads
- Maximum strain above doors and windows
- Values well above critical strain levels reported in earlier studies.

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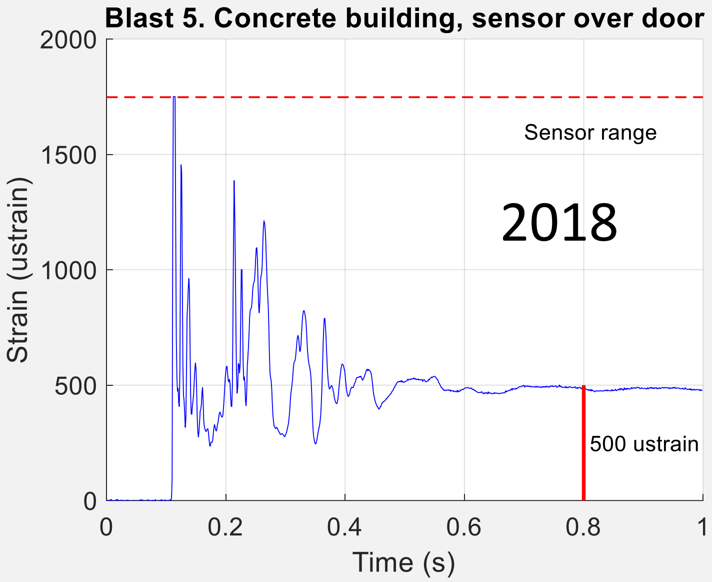
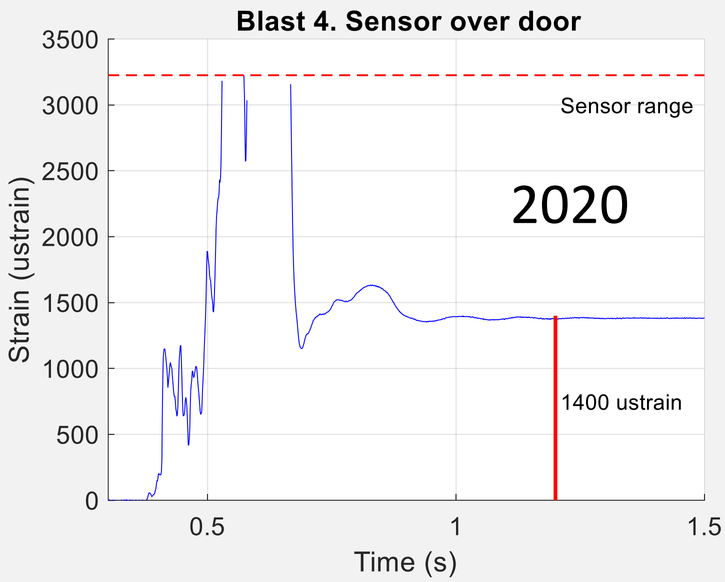
Strain





- Last blasts 2018 and 2020, sensors out of range
- 500/1400 µstrain residual strain - corresponds to 0.05/0.14 mm displacement across the 110 mm sensor

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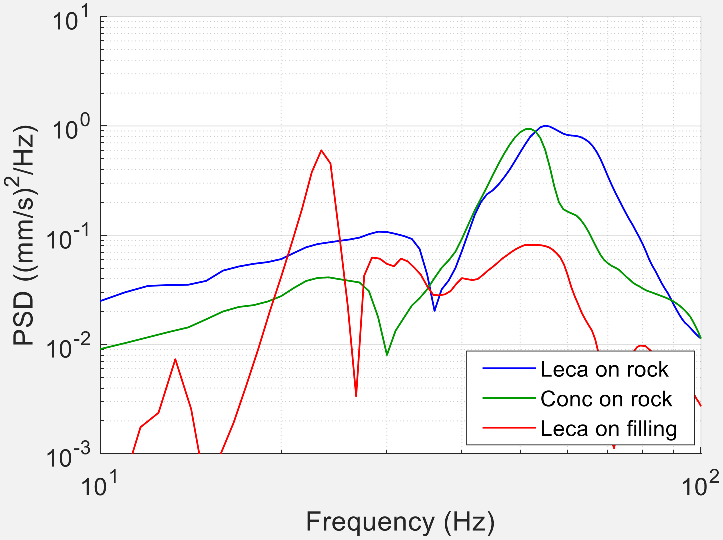
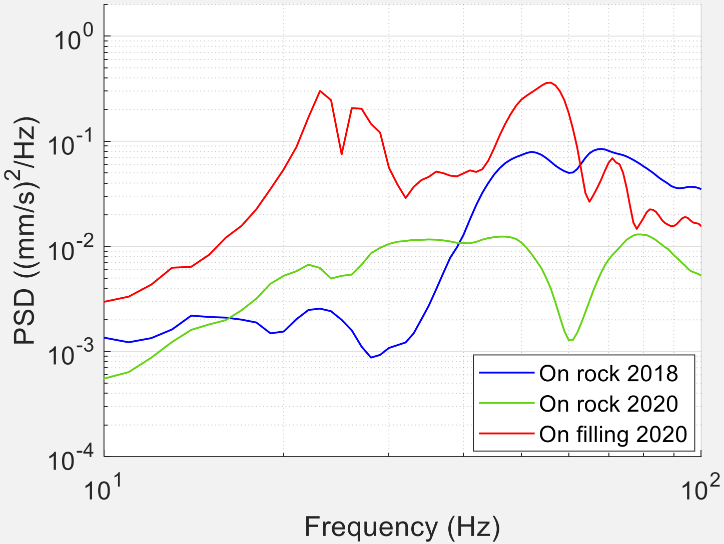
Vibration frequency

Measured on building



Measured on ground



Clearly lower frequency on the filling than on rock

Lower frequency than expected on rock

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New revision of NS 8141

- Expected to be published in 2022
- No frequency filter
- The factors used in the calculations have been adjusted and simplified
- Distance factor only for short (<10m) and long distances (>100m)
- Somewhat higher limit values on soft ground and on rock in short distance

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Norsk Standard

prNS 8141-1:2022

Publisert: 2022-02-25
Språk: Norsk

FORSLAG
Vibrasjoner og støt
Veiledende grenseverdier for bygge- og anleggsvirksomhet, bergverk og trafikk

Del 1:
Virkning av vibrasjoner og lufttrykkstøt på byggverk, inkludert tunneler og bergrom

Vibration and shock
Guideline limit values for construction work, open-pit and pit mining and traffic

Part 1: *Effects of vibration and air blast on construction works, including tunnels and rock caverns*

Standard Norge

Referansenummer:
prNS 8141-1:2022 (no)

Acknowledgments

- The field tests were carried out in collaboration between NGI, Multiconsult AS and the upper secondary school Solør VGS
- The test was financed by NPRA Directorate of Public Roads (Statens vegvesen Vegdirektoratet), National Railroad Authority (Bane NOR), Norwegian Association of Heavy Equipment Contractors (MEF), The Norwegian Defence Estates Agency (Forsvarsbygg) and Norwegian Contractors Association (EBA).
- The analysis of the results was performed with support from the research project Remedy (Risk Reduction of Groundwork Damage), funded by the Research Council of Norway, Grant Agreement 267674