Cautious Blasting in Urban Areas

Society for Rock Mechanics & Engineering Geology
Singapore, 07-12-2012

By Sjoerd Spijkerman

Opening Blast by Speaker

About the Company

- Swedish company in the field of tunneling and surface rock works
- Specialized in rock engineering/ cautious blasting in urban areas
- Network of associated companies working together in larger projects

Following Services

- Blasting consultancy (charge calculation, drilling design, vibration monitoring, production sequence design, air-shock wave calculation)
- Blasting services (drilling and blasting, rock and concrete fracturing)
- Engineering geological services (engineering geological design and calculation, rock support)
- Planning, cost estimates/cost control
- Quality checks (analysis and design followups)
- Geological services (mapping bed-rock, tunnel mapping, groundwater studies)
- Construction management

Seminar topics

- General blasting issues
- Bench blasting / Tunnel blasting
- Vibration monitoring
- Alternative methods
- Example: City Link railway project

Cautious & Smooth Blasting

- Cautious blasting: blasting without causing damage to the environment
- Smooth blasting: blasting without causing damage to the remaining rock

”A great difficulty when it comes to determining the limit values for varying degrees of damage is due to the fact that there have been relatively few cases where damages could be proved”

From Modern technique of rock blasting by Langefors and Kihlström, 1963

Common Blasting Projects in Urban Areas
High Priced Ground

- Foundation for building/construction/bridge projects
- Removing roads/railroads subsurface
- Removing cables/pipelines/sewer/drainage into tunnels
- Free surface ground for housing/offices, build below (storage, sporting arenas, parking, shopping)
- Cooling/heating plants

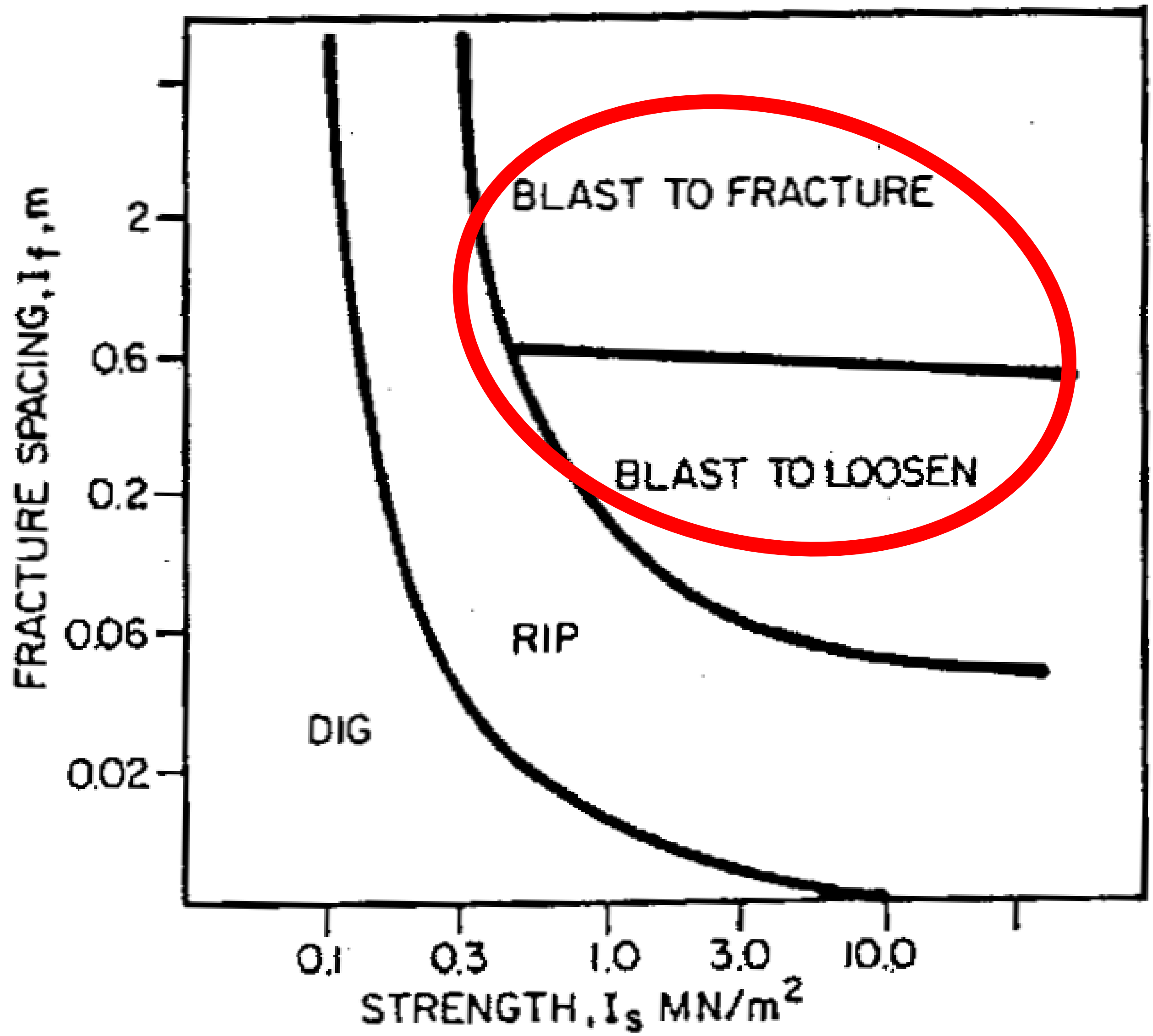
Conclusion: blasting is getting more complicated

Basics on Blasting

- Preparation works (permits, design, calculations, planning, time-cost estimates)
- Drilling
- Charging and detonation design
- Firing and safety control
- Mucking
- Cleaning and scaling
- Rock support
- Analyse of blasting procedure

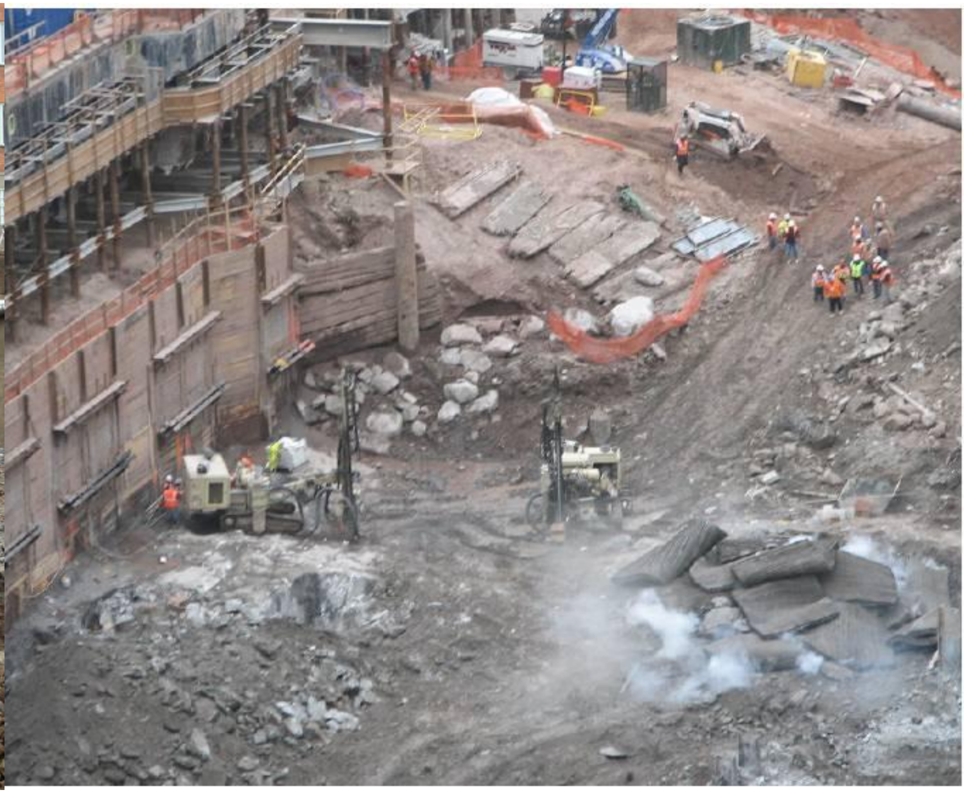
Most Important: Geology

Considerations for Rock Excavation



Assessment of rock rippability based on field mapping (Franklin et al (1971).

Bench Blasting



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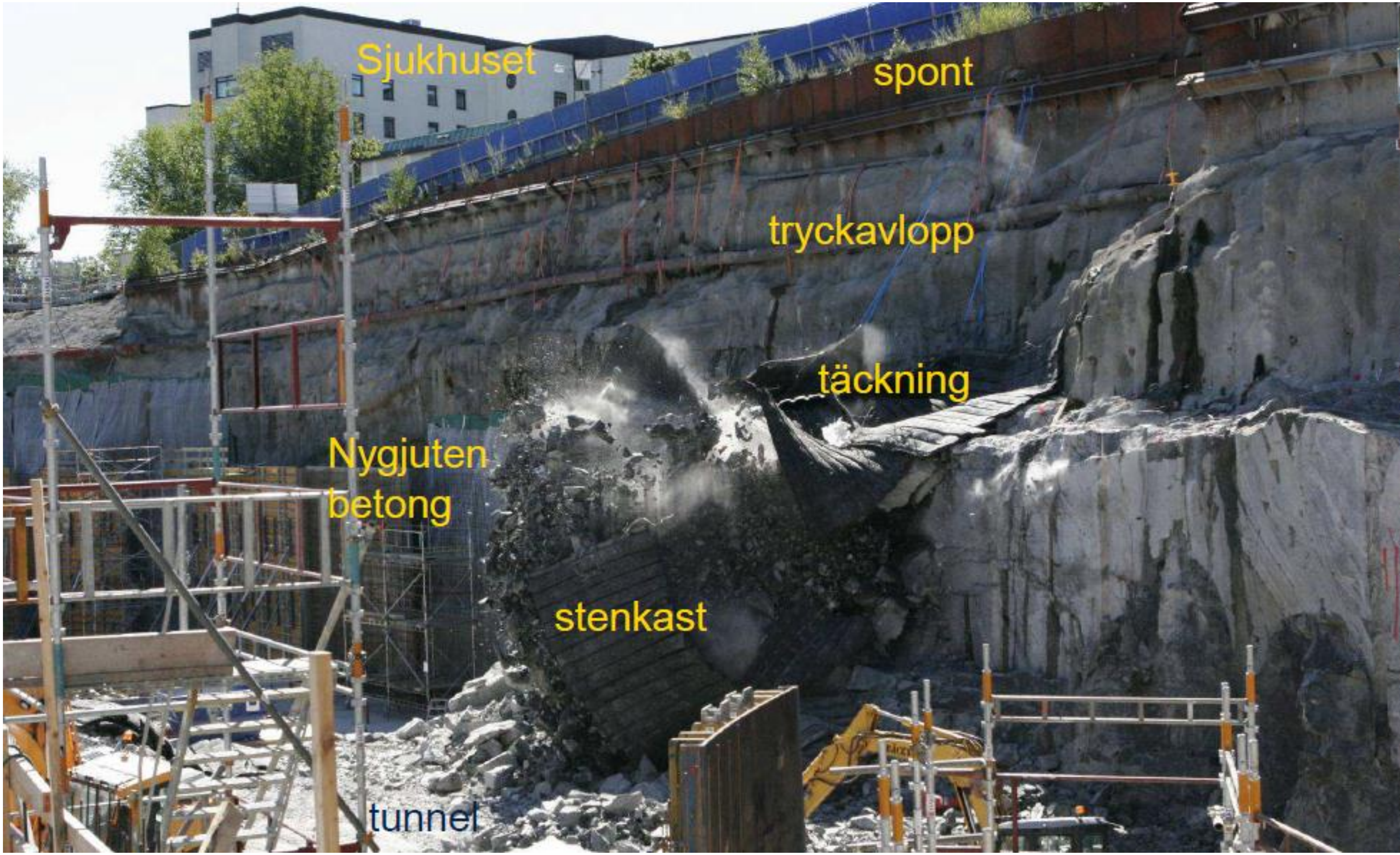
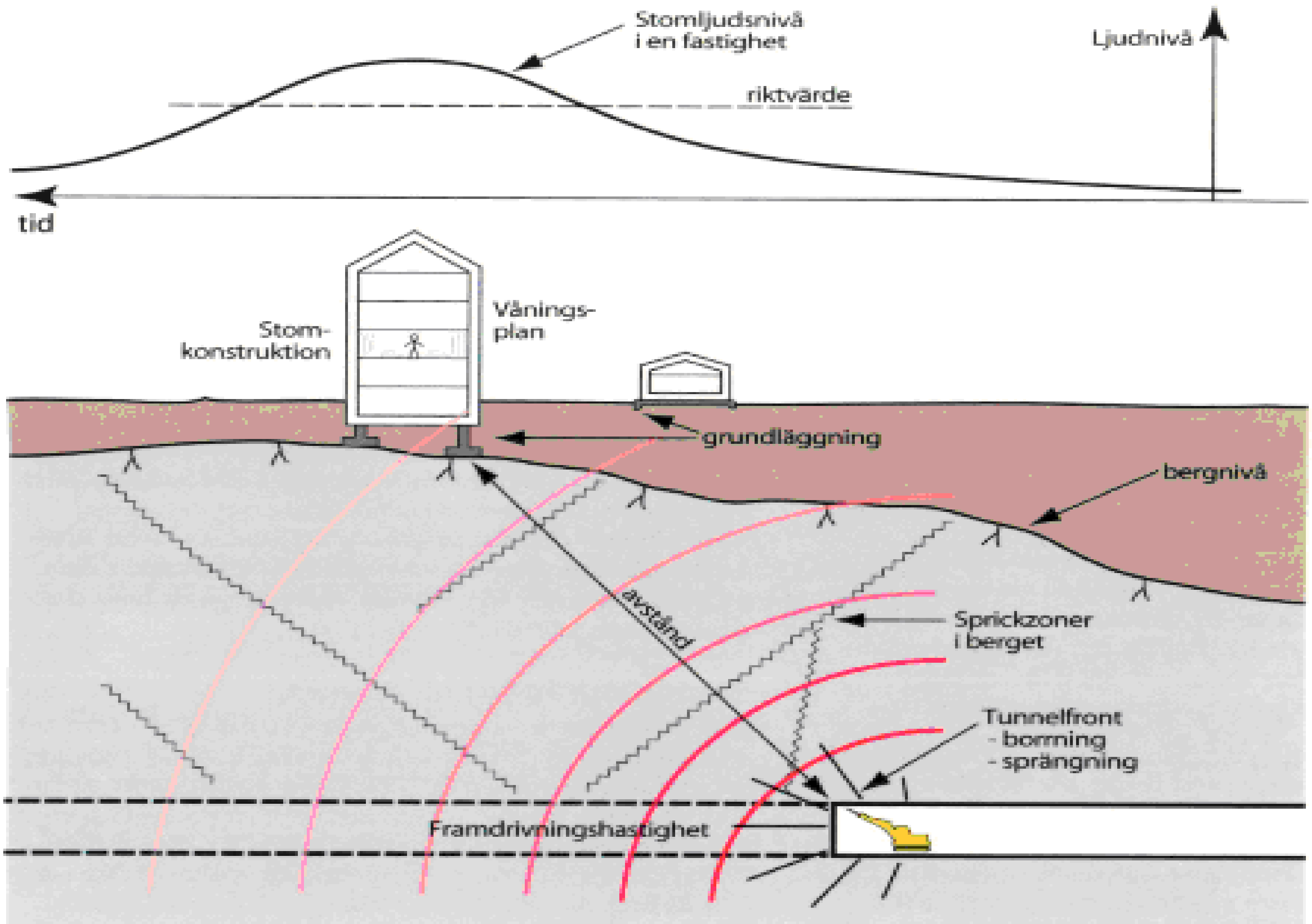
Tunnel Blasting

Risk Analyses Before Blasting

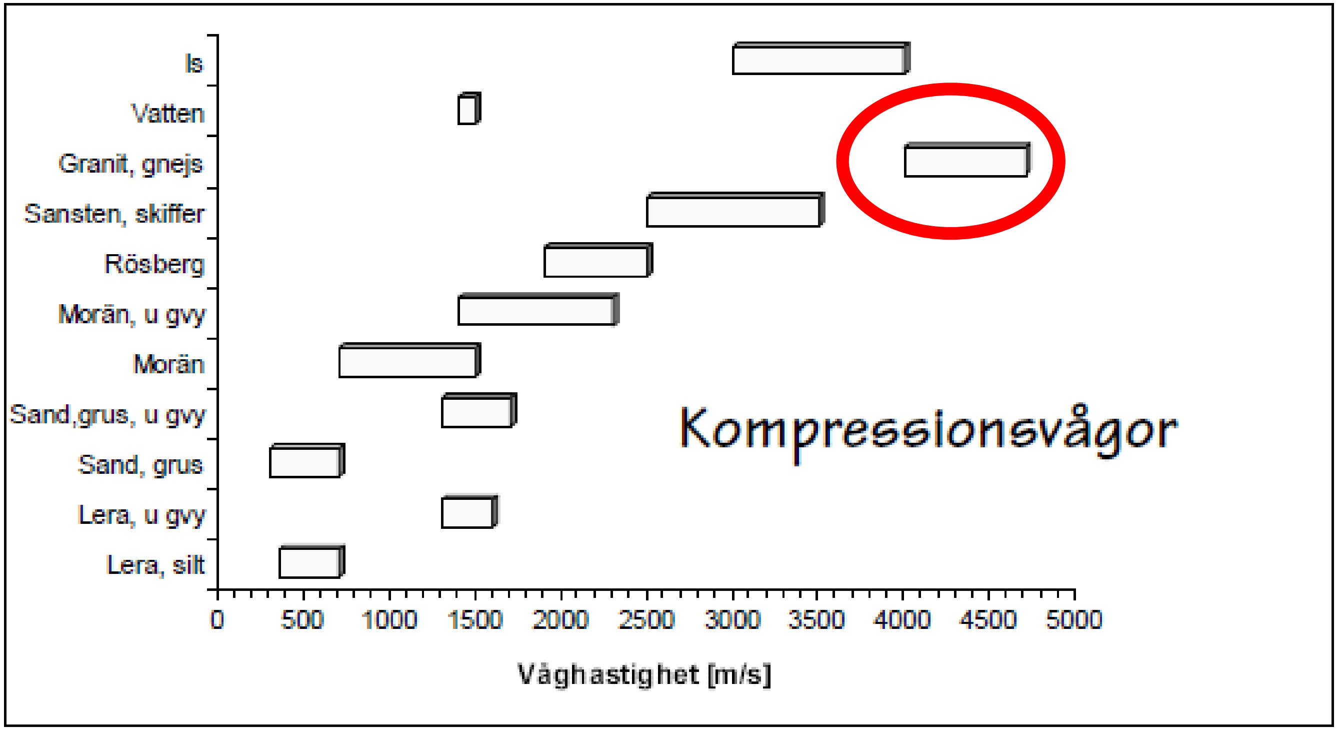
Risks in urban area blasting

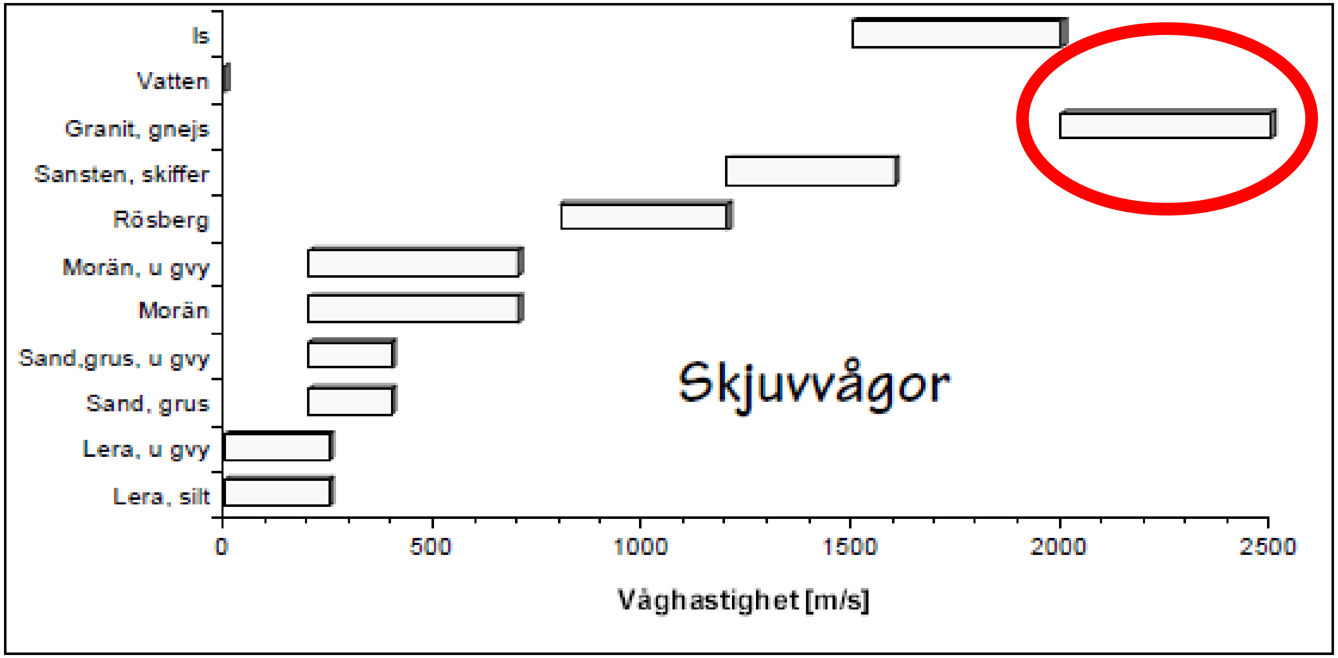


Factors Influencing Blasting Effects



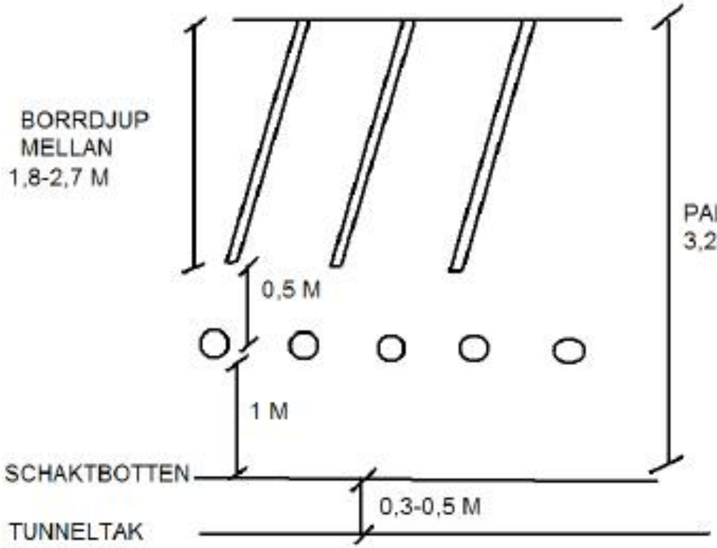
Differences in P-waves and S-waves

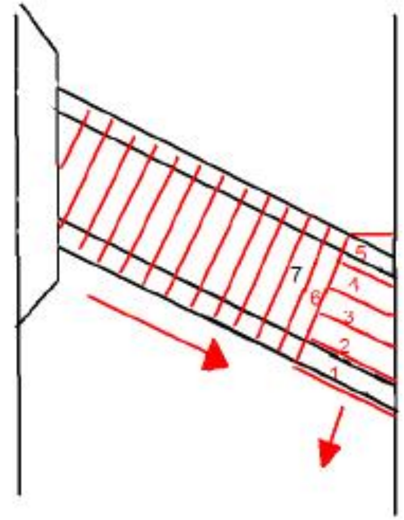





Drilling is the key to successfull Blasting

Drilling Design Pattern





Rock excavation on top of tunnel

Results…

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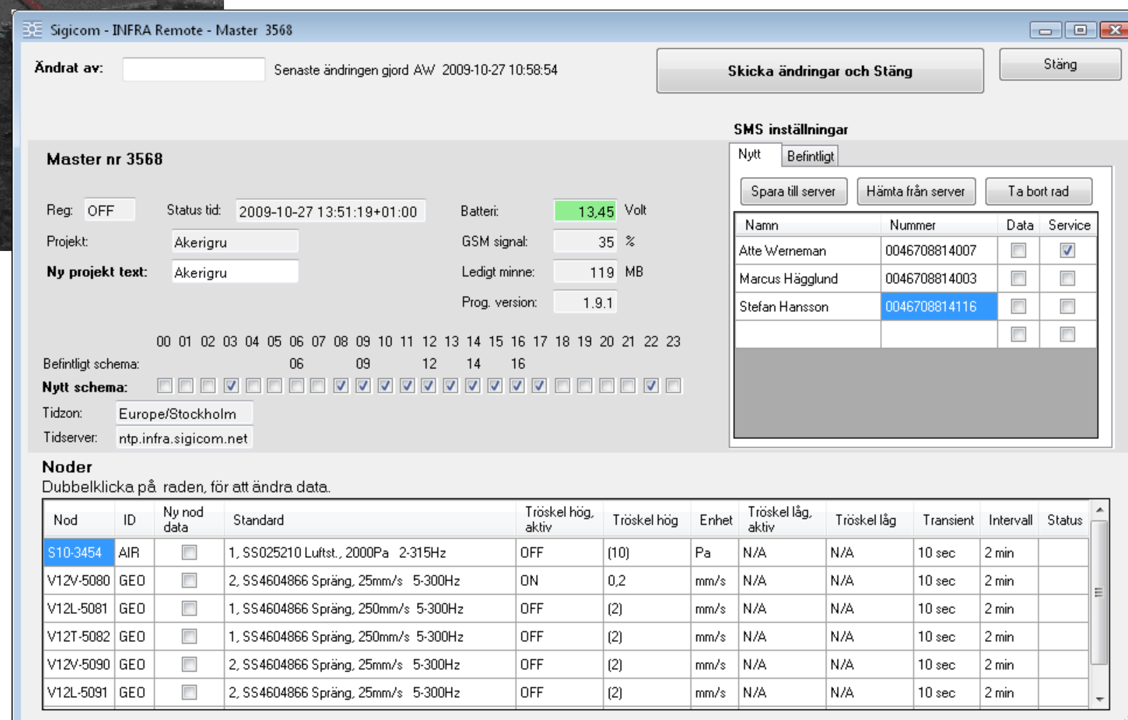
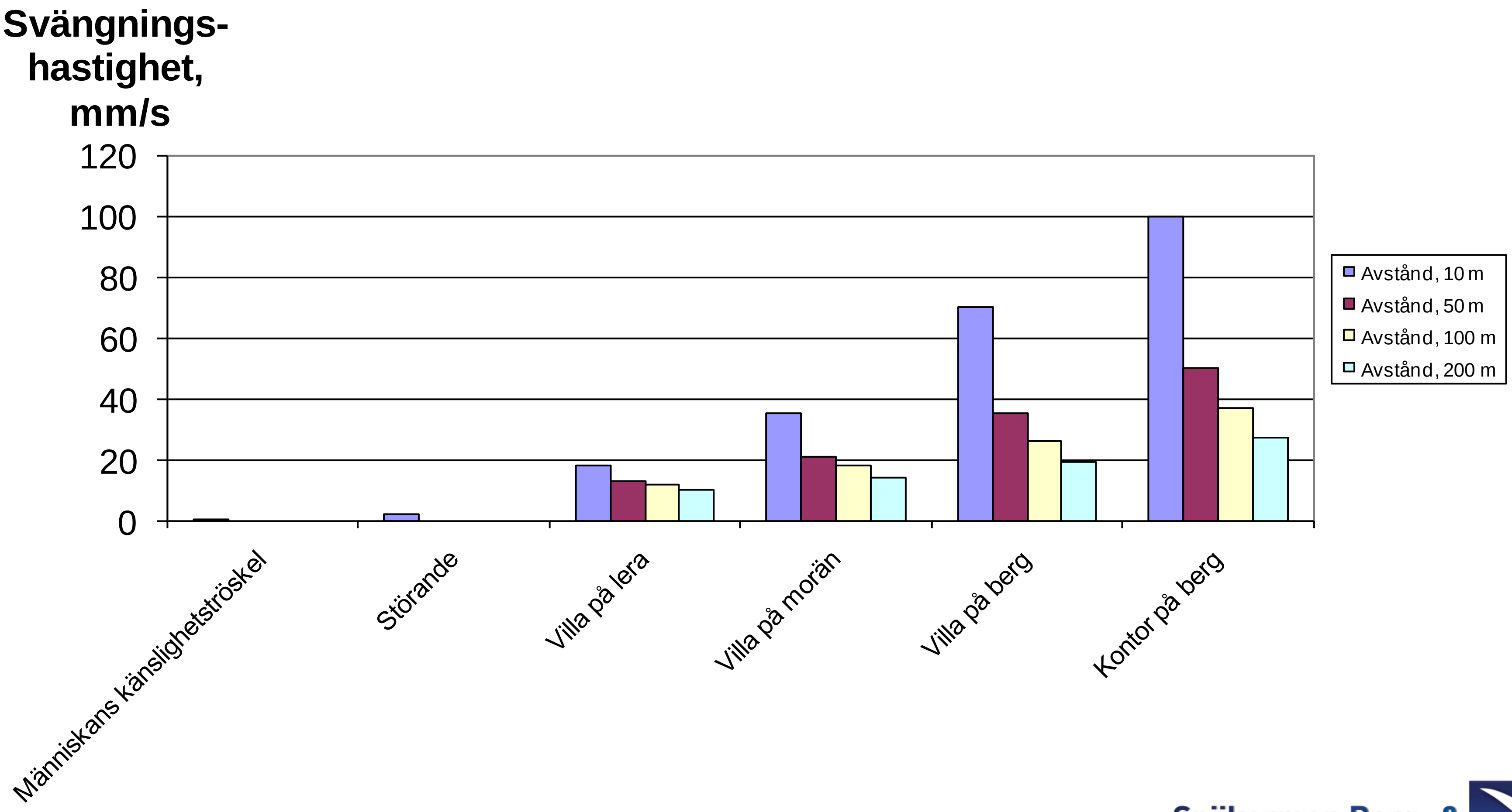
Vibration Equipment

All instrument with GSM modem

Automatically transfer data to NCVIB.com



Guide Values (PPV) for Different Types of Buildings



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Utility tunnels – guide values

Type of tunnel	PPV, mm/s	PPD, mm
Metro tunnels in rock (traffic operating)	60 – 92 (30)	-
Metro tunnels – concrete (traffic operating)	100 (30)	-
Utility tunnels	70 or 100	-
District heating pipes	-	300[1)] mm
[1)] Replaces rule that no blastings when temperature below -10 C		

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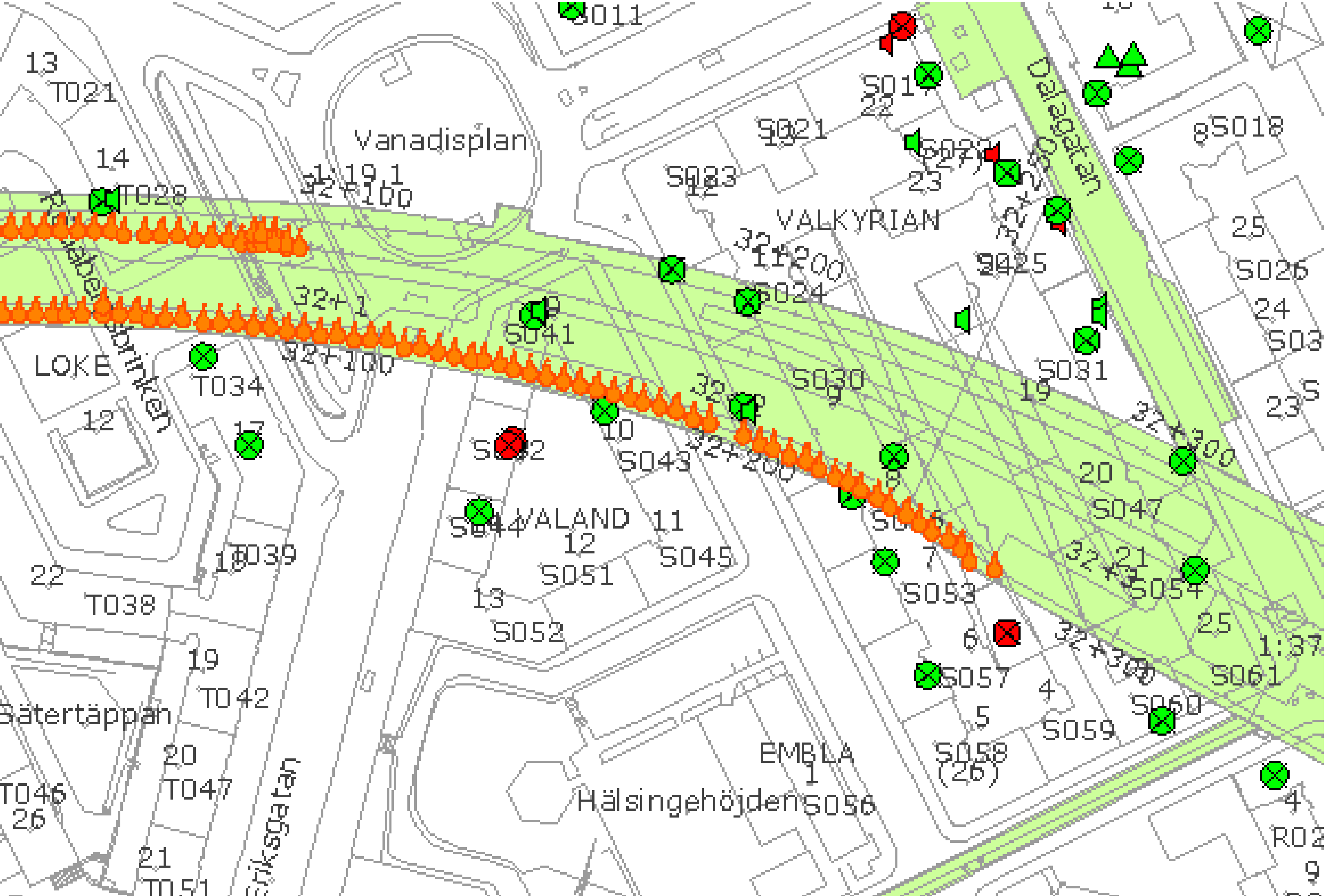
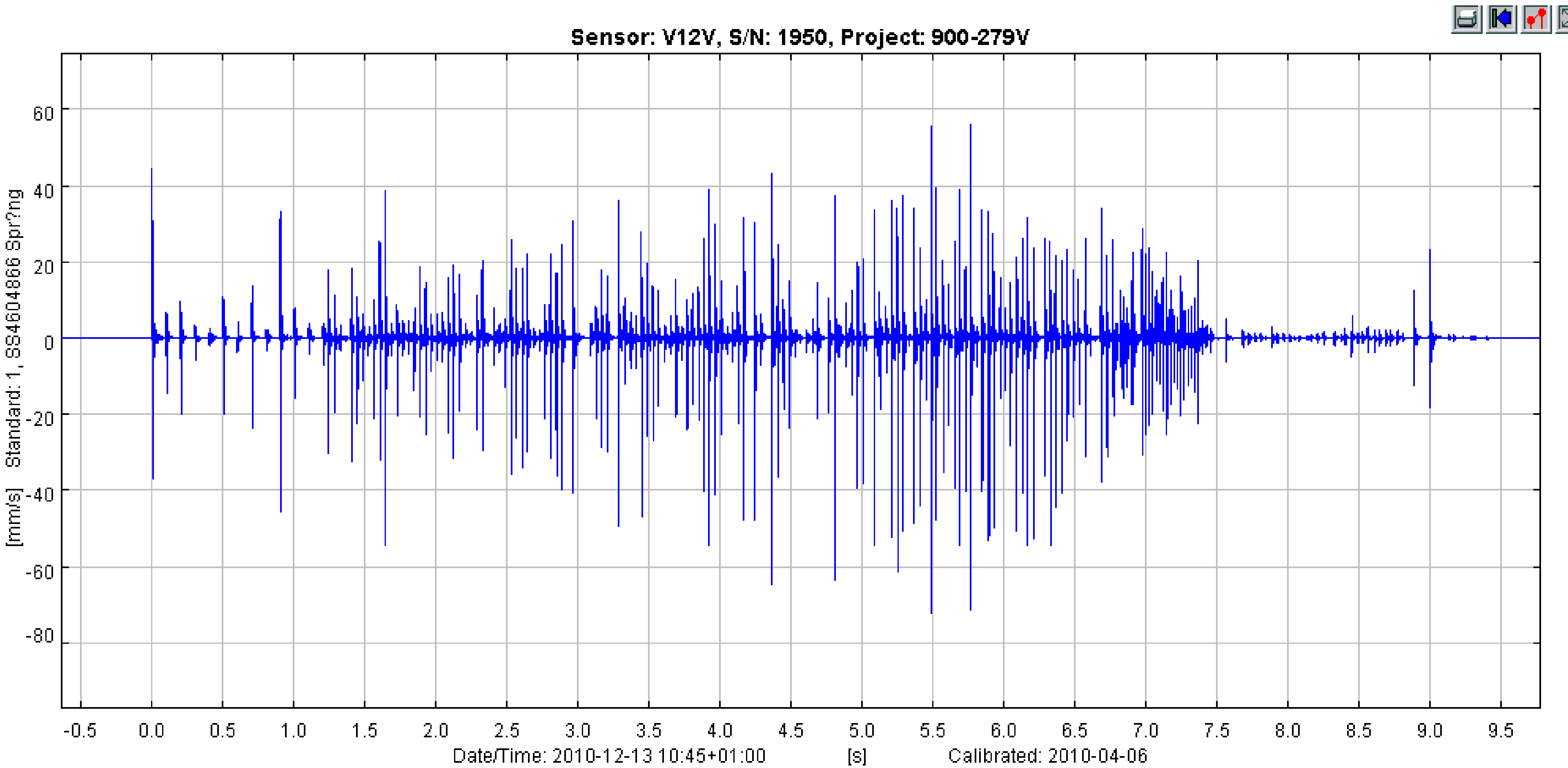
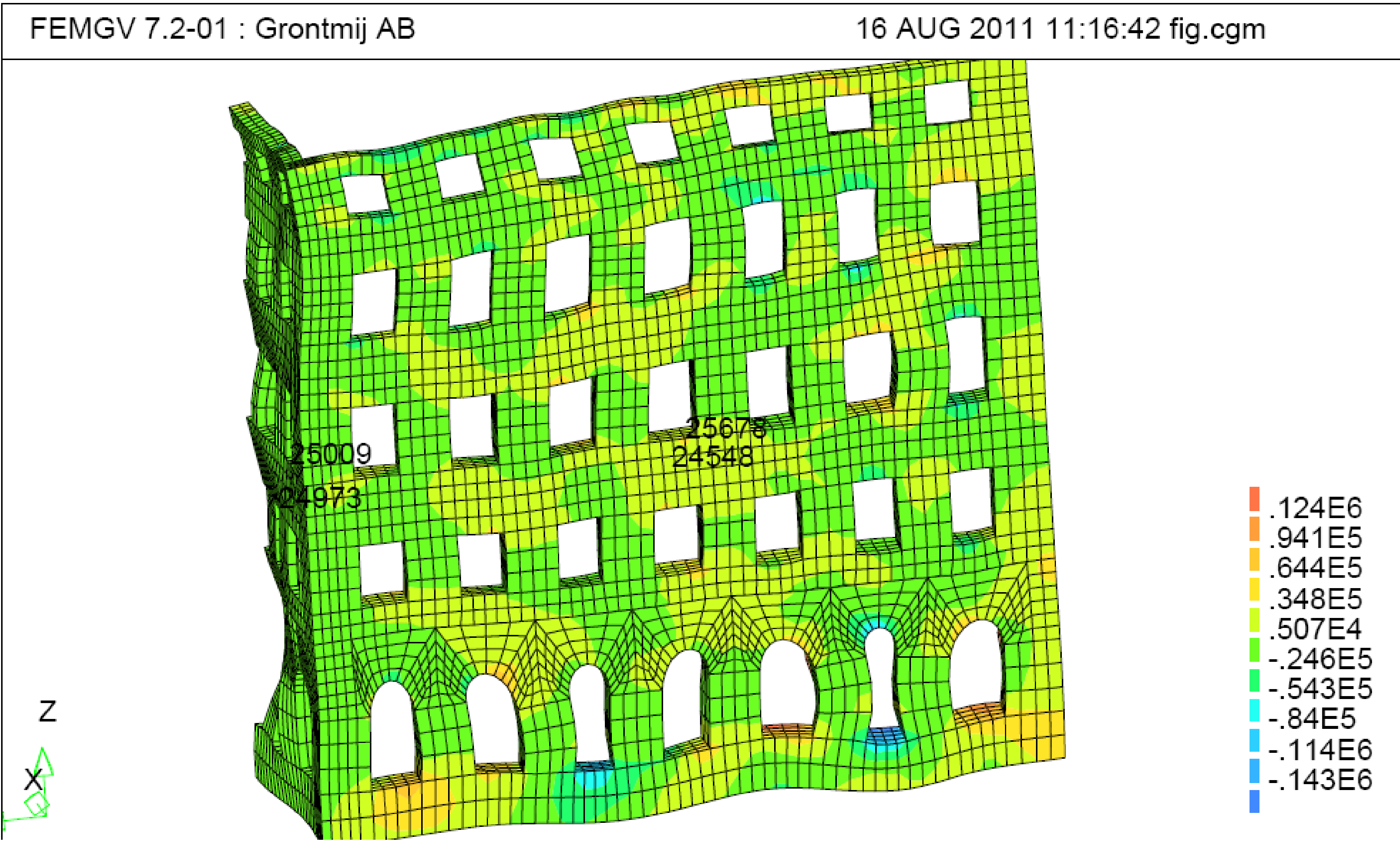
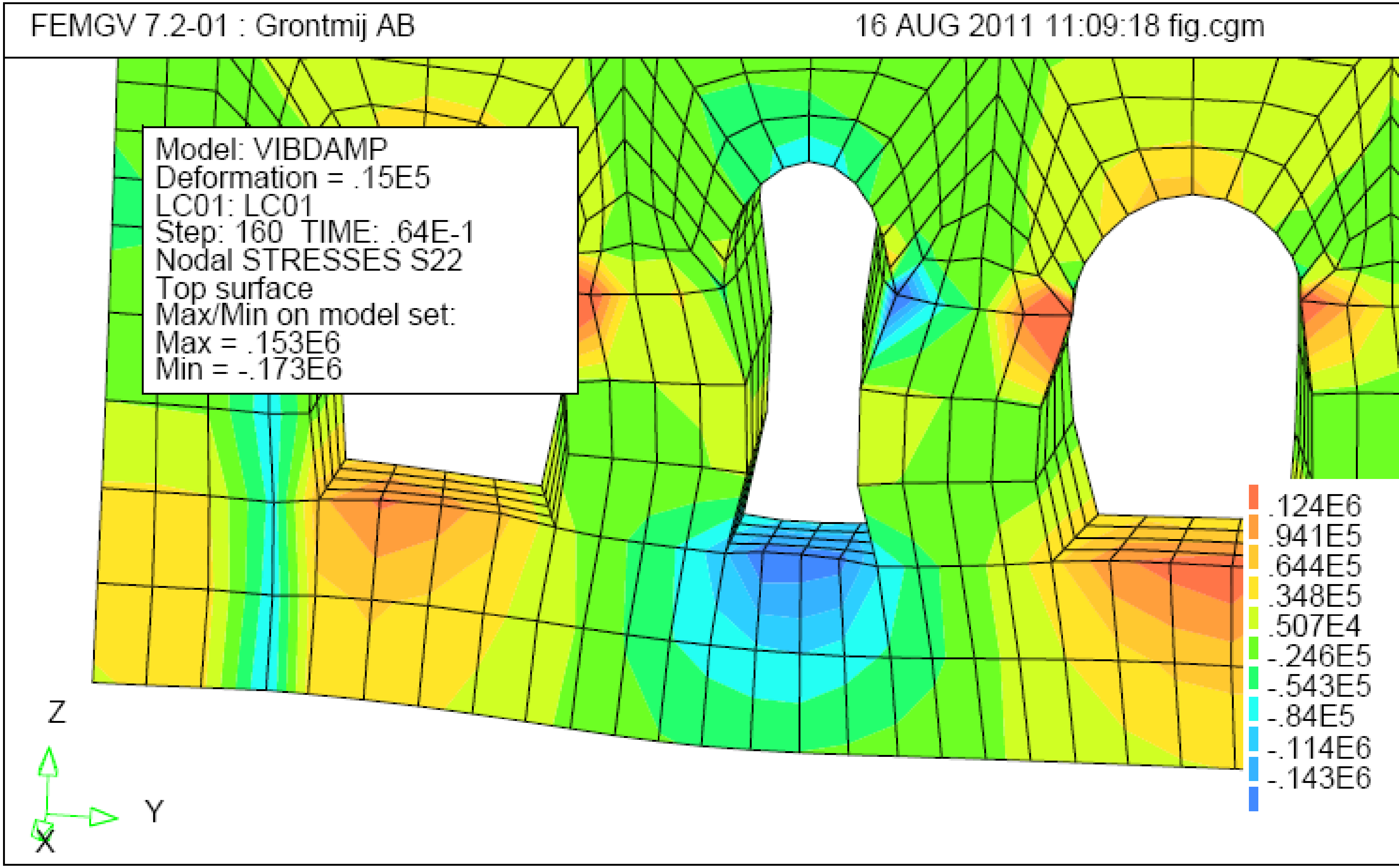

S011
13
T021
Vanadisplan
14
T028
32+100
32+1
LOKE
T034
12
32+100
S041
S017
22
S021
S023
23
VALKYRIAN
Dalagatan
S018
25
S026
S025
S024
24
S030
S031
19
23
S043
S044
VALAND
12
11
S045
S051
T039
22
T038
13
S052
20
S047
21
S053
S054
25
6
S057
S061
4
5
S059
S060
S058
(26)
EMBLA
1
Hälsingehöjden
S056
19
T042
Sätertäppan
20
T047
T046
26
21
T051
Eriksgatan

Electronic Detonators
Unlimited Time Delays

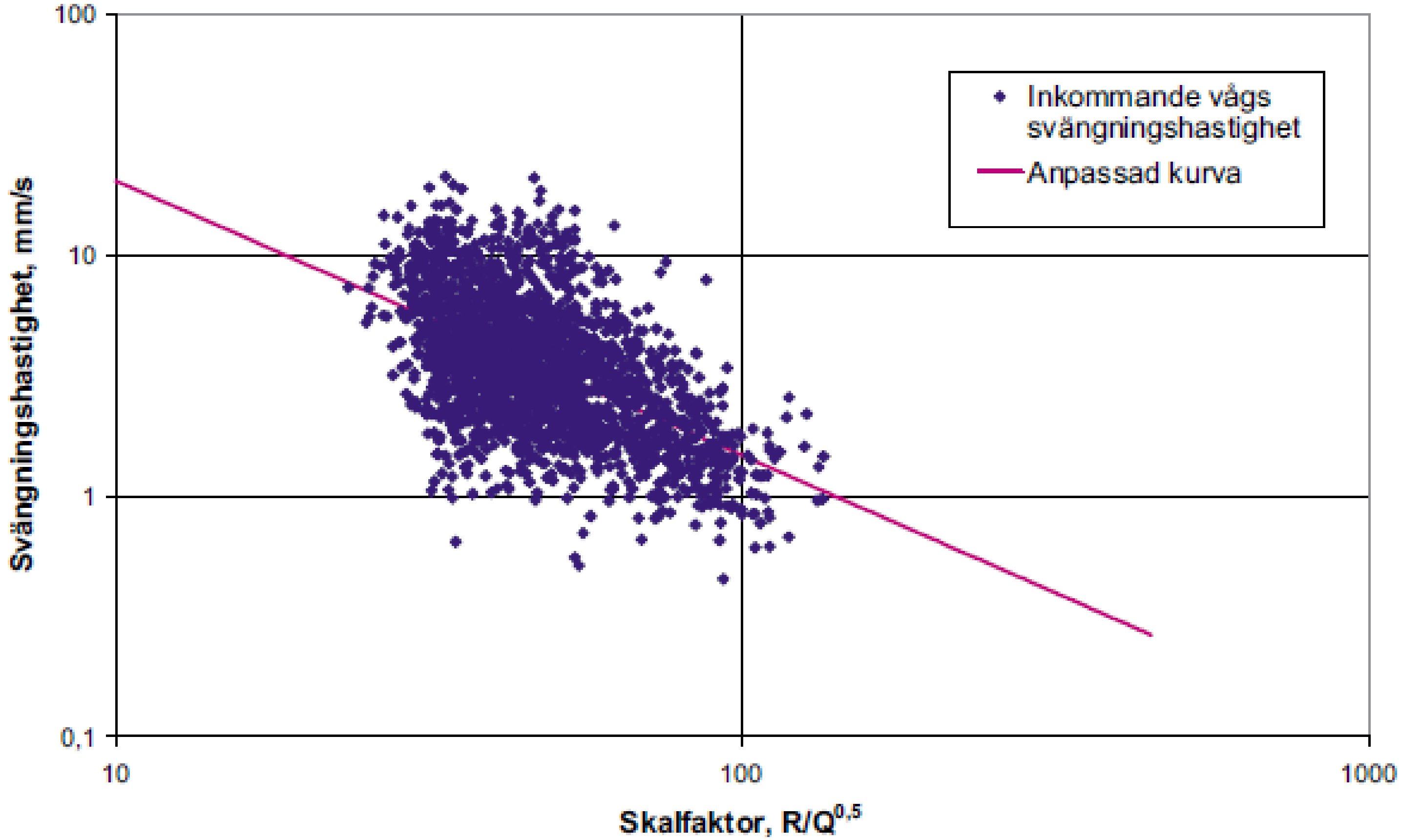


FEM modelling vibrations




FEMGV 7.2-01 : Grontmij AB
16 AUG 2011 11:09:18 fig.cgm
Model: VIBDAMP
Deformation = .15E5
LC01: LC01
Step: 160 TIME: .64E-1
Nodal STRESSES S22
Top surface
Max/Min on model set:
Max = .153E6
Min = -.173E6
.124E6
.941E5
.644E5
.348E5
.507E4
-.246E5
-.543E5
-.84E5
-.114E6
-.143E6
Z
Y
X

Analysis of Blasting Results



Formeln brukar kallas

$$v = A \cdot \left(\frac{R}{Q_{sam}^{0,5}} \right)^{B}$$

där

v = förväntad svängningshastighet [mm/s]

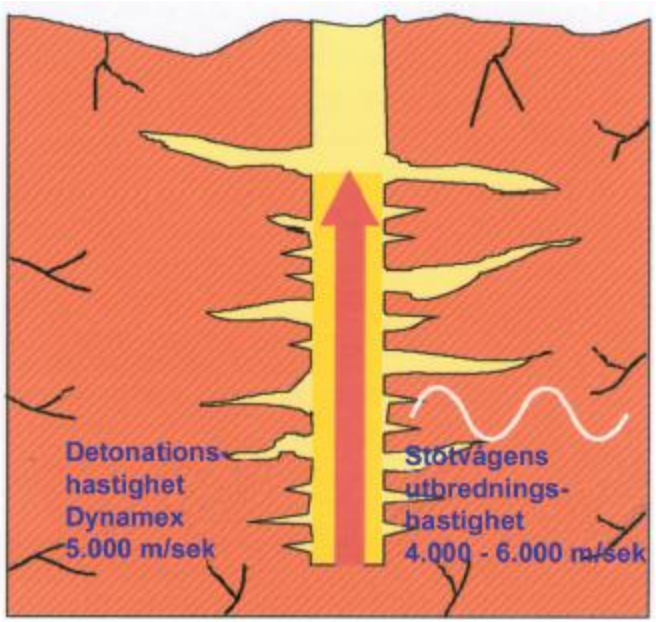
R = avstånd mellan salvans sprängcentrum och mätpunkten [m]

Q_{sam} = max samverkande laddning [kg]

A och B = konstanter som beror på geologi, geometri och sprängtekniska förhållanden.

Choice of Explosives

The Behaviour of an Explosive



- Detonation velocity
- Strength
- Detonation stability
- Flash-over capacity
- Density
- Water sensitivity
- Detonation sensitivity
- Safety characteristics
- Environmental characteristics

Conclusion: the contractor must have a range of Different products in order to perform a successful blast.

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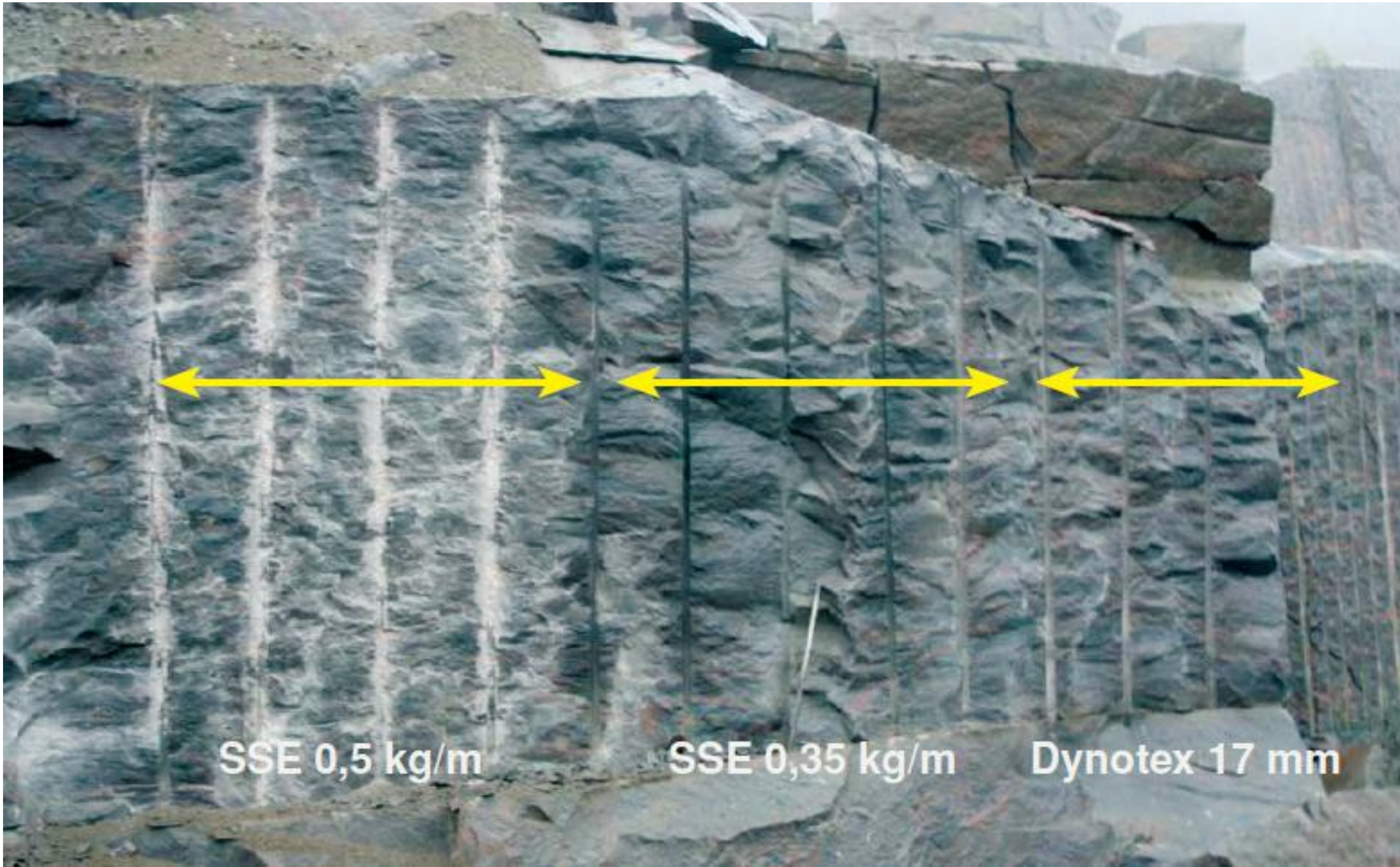
Blasting Cord, But Splitting Along Crack

Damage zones of different explosives




Dynotex 17 mm
2011/01/12 11:42

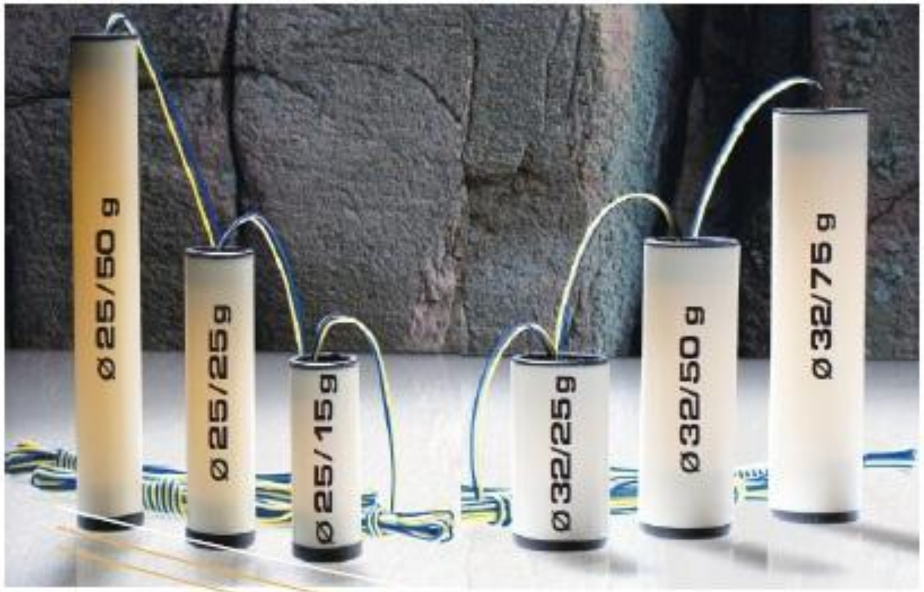
Alternative Mechanized Methods

- Chipping /Hammering
- Fracturing hydraulic (fracturing tools or chemicals)
- Cutting the rock (Roadheader, diamond wire saw)




Rock Cracking Cartridges

- *Hög säkerhet*
- *Låga vibrationer*
- *Låga tillståndskrav*
- *Kostnadseffektiv*



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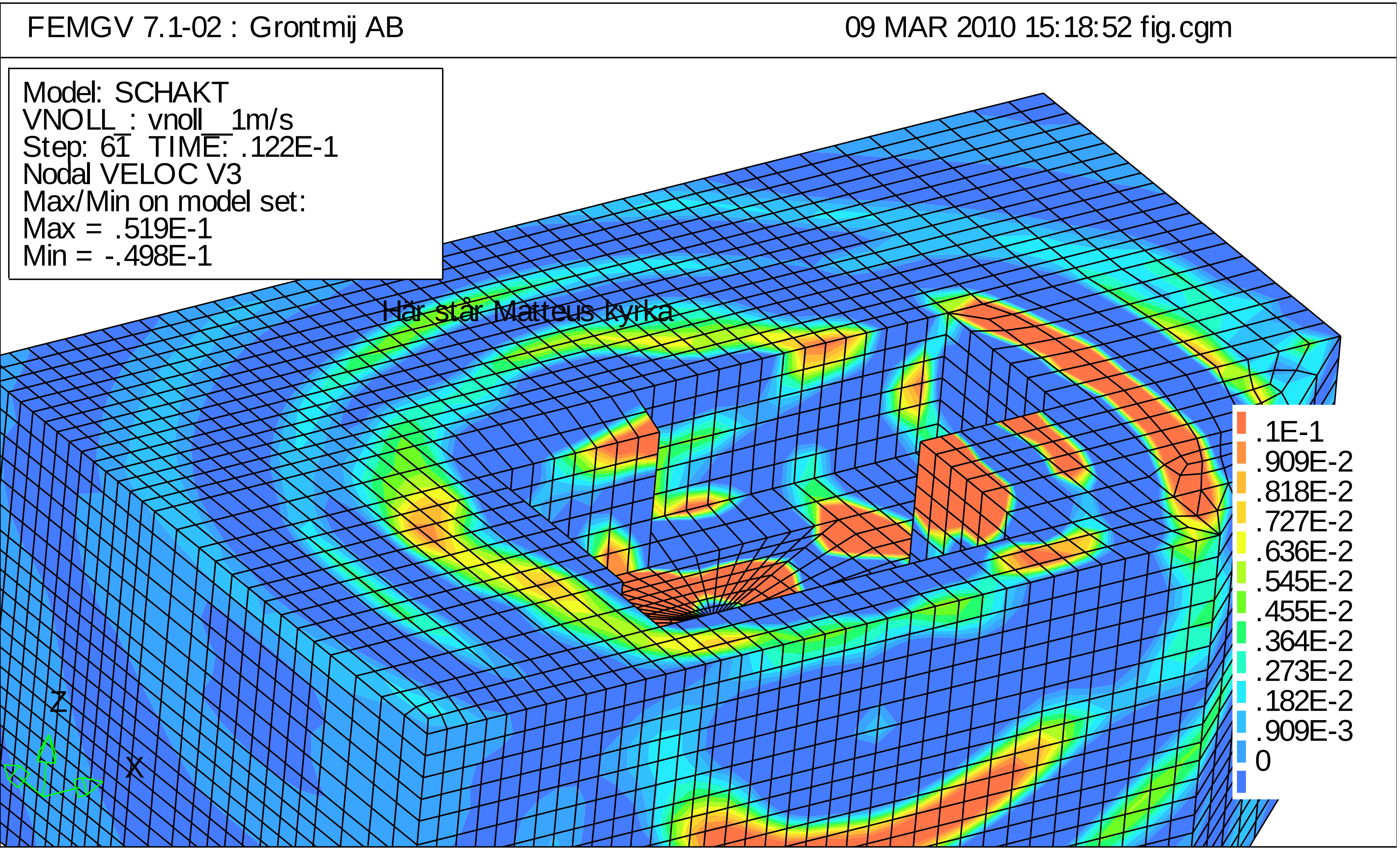
Wire Cutting All Contours

Wire Cutting

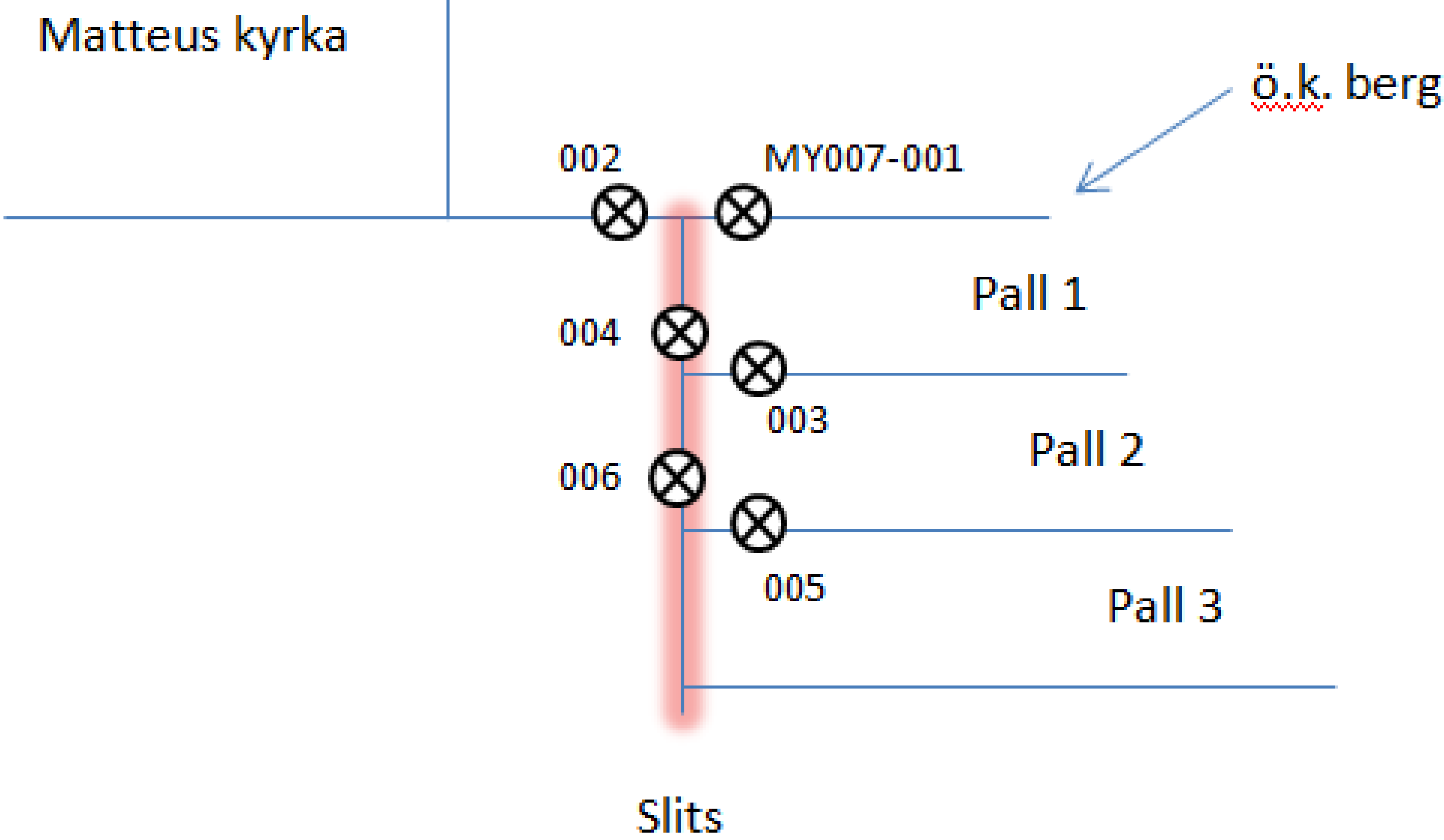
FEM Analysis
Effect of a Slot in the Contour



Result of FEM Analysis

	Dampening degree, PPV vertical direction
Bench 1	80 %
Bench 2	84 %
Bench 3	72 %

Monitoring Points



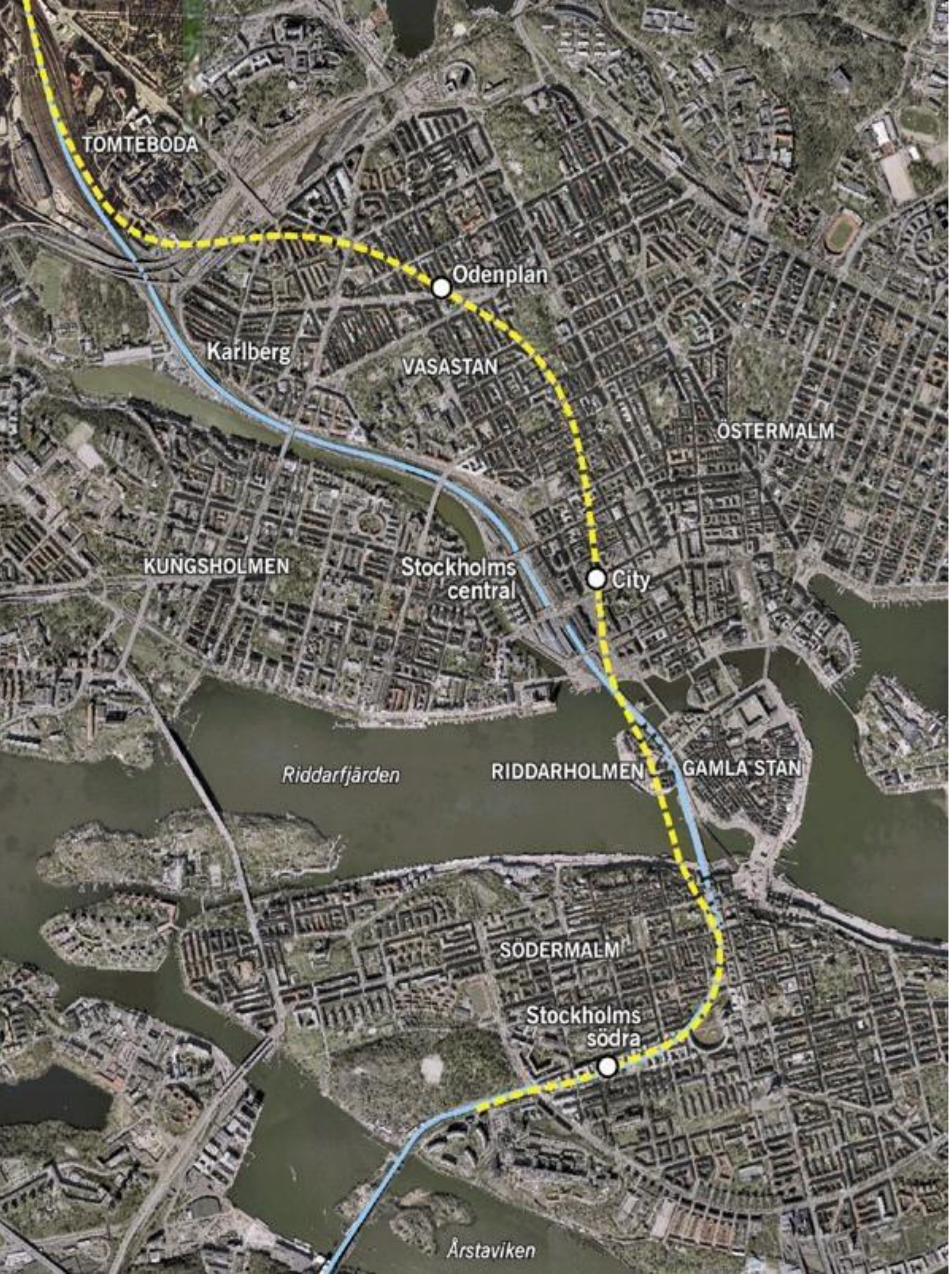
Average Damping Ratio

Monitoring Poing	Damping ration – bench 1, [%]	Damping ration – bench 3, [%]
Behind the slot, Vertical direction	72	71
Behind the slot, Longitudinal	50	61
Behind the slot, Transversal	42	33
Church, MS013-003, Vertical	77	75
Church, MS013-005, Vertical	69	37

Data provided by Nitro Consult

Example of Urban Blasting Project

Stockholm City Link Railway project



6 km railway tunnel

\+ 2 tracks

3 stations

1,5 km fly over bridge

=

Double capacity & easy availability

270 shops

14 hotels

14 workshops

15 physiotherapist centres

787 offices

4 highschools

10 rehabilitation centres

35 000 residents/working

6 film/sound studios

15 preschools

7 educational centres

10 churches

4 theatres

9 courts of justice

25 hospitals/dentists

96 restaurants

8 yogacentres

What is directly above the blasting area?

Risk Investigation Area

- Approx. 2000 Buildings above the rock tunnels
- 13 crossings with utility tunnels – rock cover 0 to 10 meters
- 70 electrical substations
- 60 switching center for Telecommunications
- 4 crossings of metro tunnels & stations

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Blasting for a New Metro Station

Potential Damage Risks

Relationship between natural frequency of wall and frequency of imposed vibration. Damages can be caused by:

- Elongation
- Shearing
- Bending

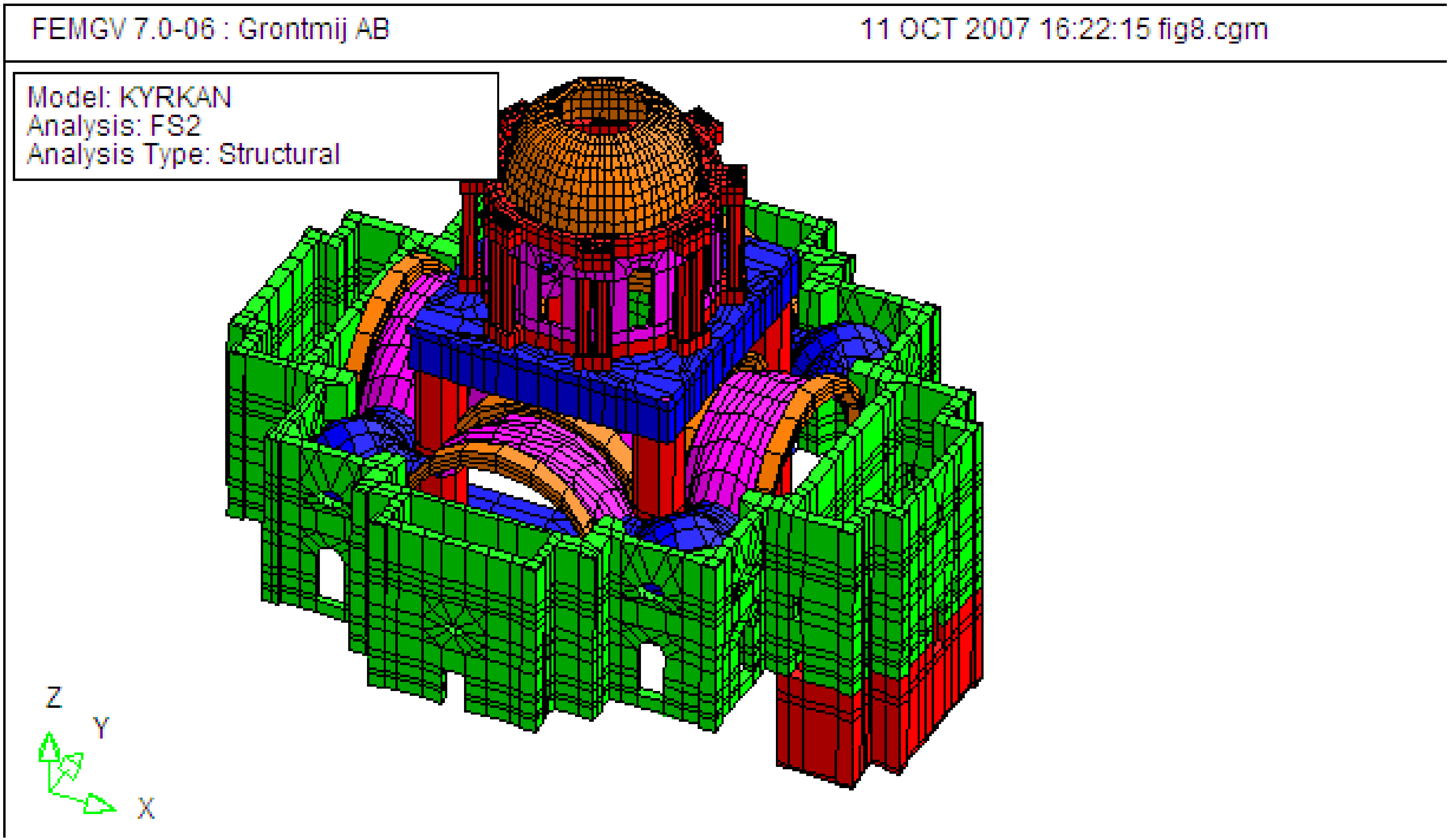
Existing static state of building unknown…

Foundation unknown or transfer mechanism between foundation and building unknown…

Vibration energy…

Solution: FEM modelling or conservative attitude

FEM Model of Gustaf Vasa Church



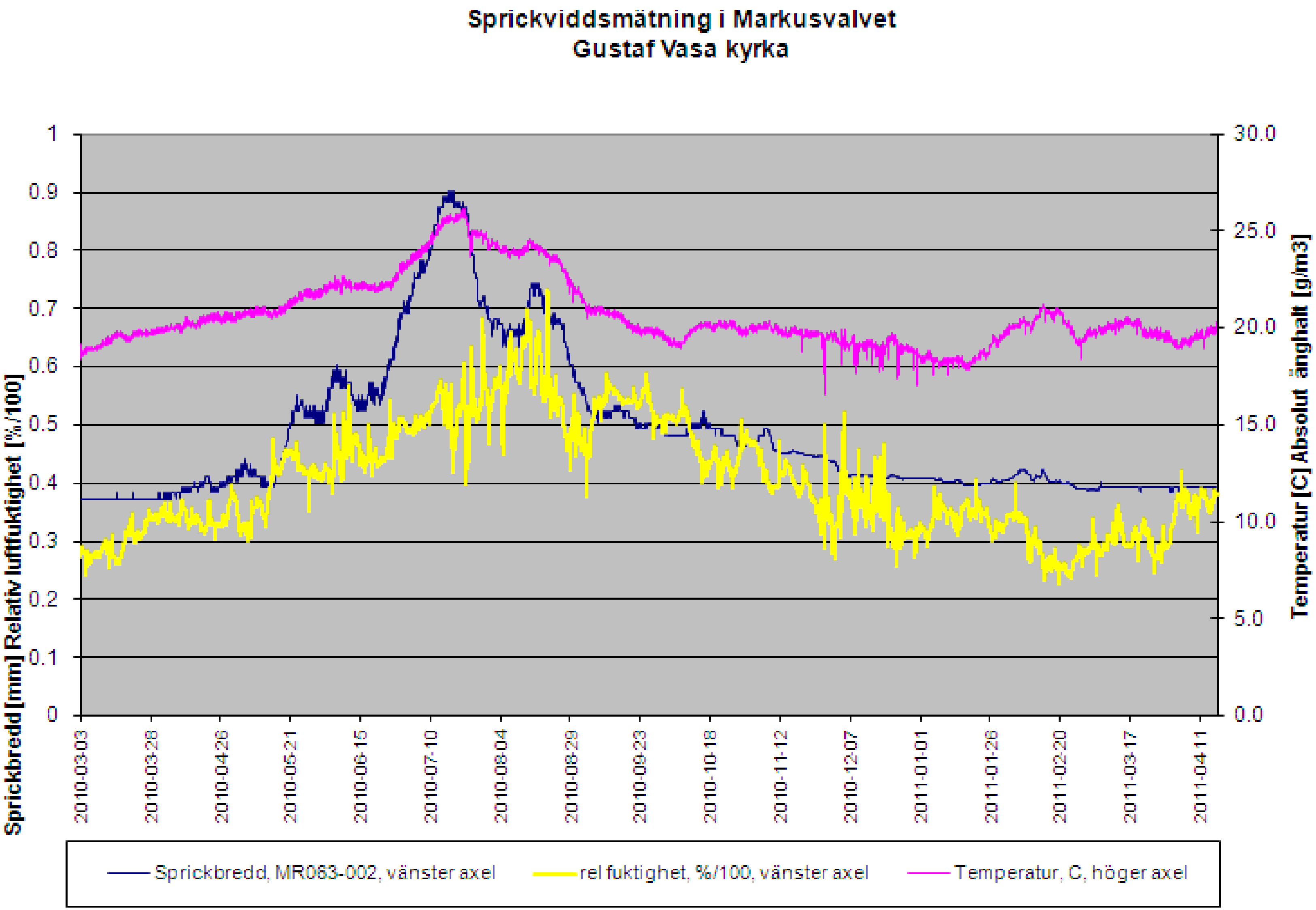
Results of Analysis

Part of the Church	Safe value, PPV mm/s	Comments
Foundation and Columns	30	Theoretical limit for new cracks 36 mm/s (tensilse strength 200 kPa)
Columbariet	20	
Arch vaults (Johannes, Matteus, Lukas)	20	Acceleration 4,8 g
Arch vault (Marcus)	15	Safety factor set at 5 for avoiding loosening of plaster
Altar Piece	10	Incoming vibration measured at floor level

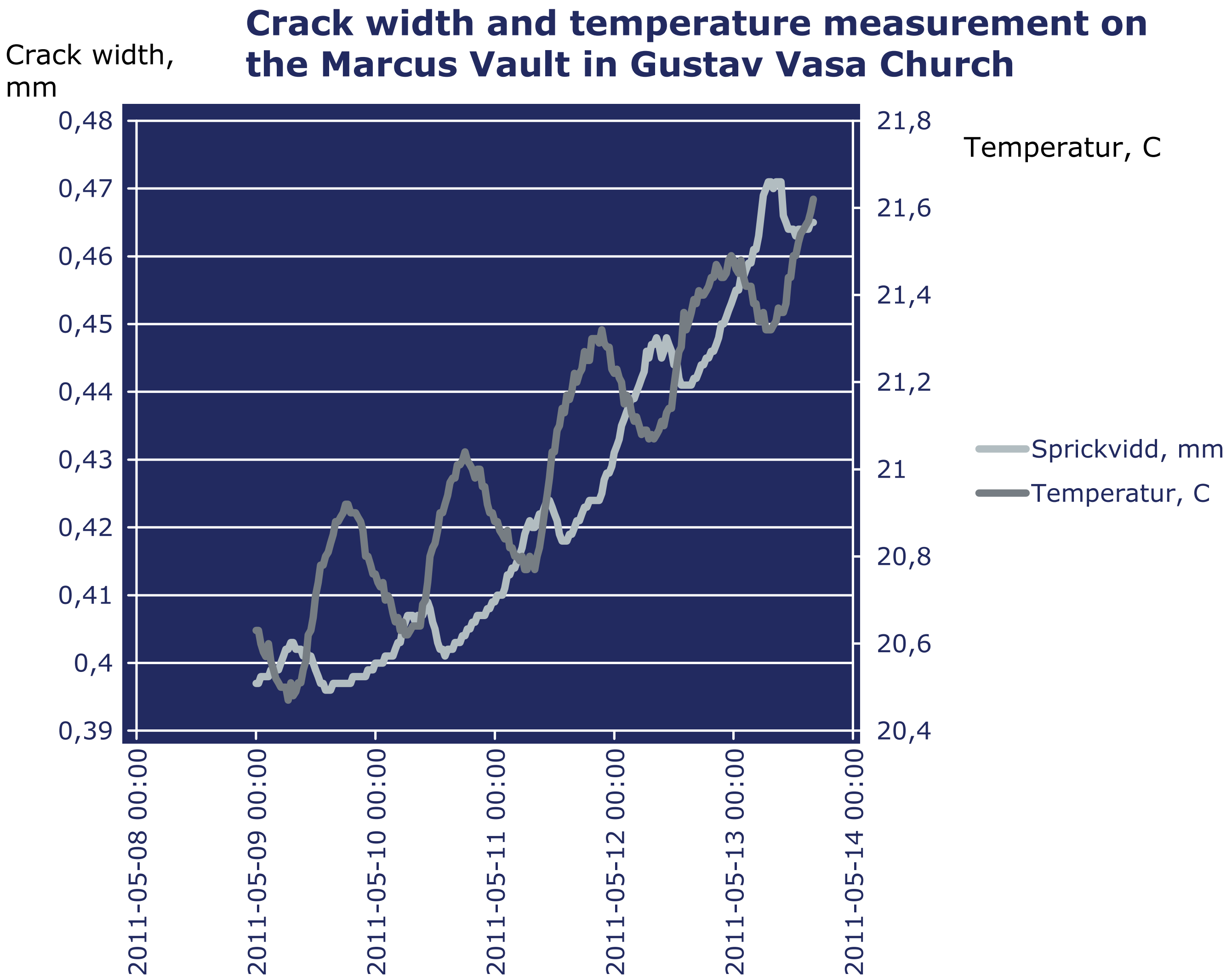
Permitted Vibration Levels in Churches

Church	Permitted PPV, mm/s	Alarm value, mm/s	Comments
S:t Matteus Church	22	13	
Gustaf Vasa Church	18	13	
S:t Clara Church	12	5	Distance >40 m
Adolf Fredrik Church	7	3	Foundation on sand/gravel. Distance >130 m
Maria Magdalena Church	10	7	Foundation on sand/gravel.

Crack Monitoring



Crack Monitoring

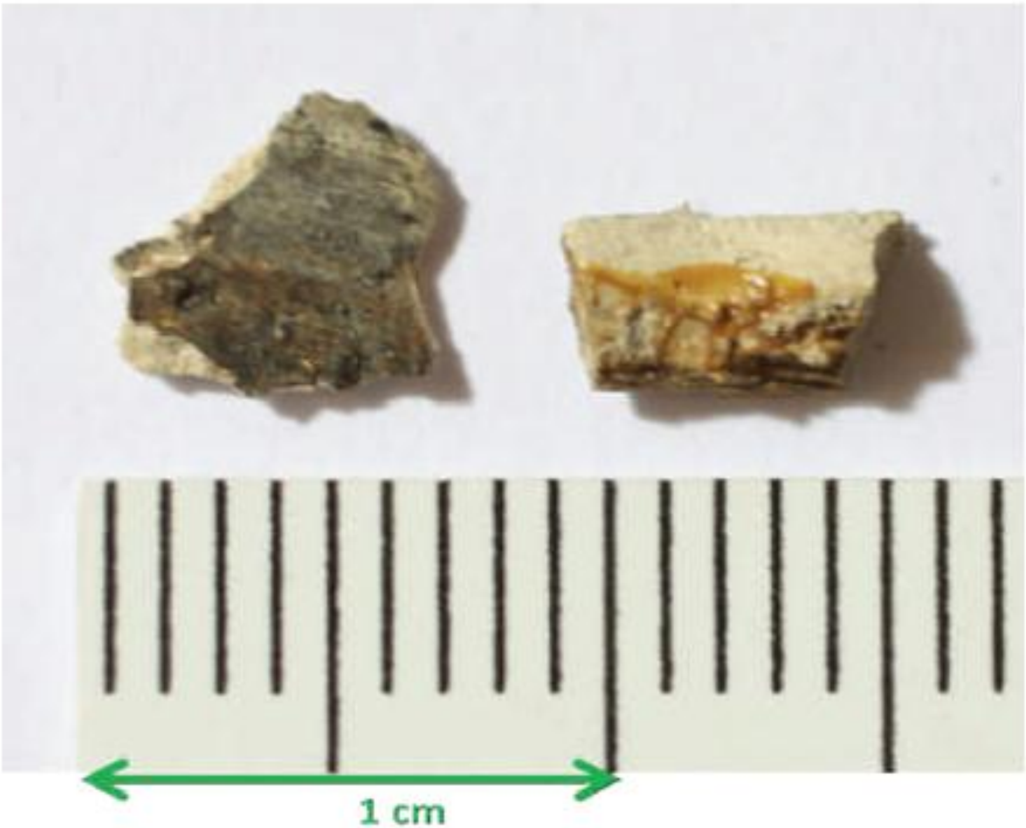


Damages - Natural Causes or Blasting?

Fotodokumentation

Lokalisering av registrerade skador

Tillvarataget material från skadeställe 2 – detaljbild 2a och 2b



Conclusions

- Blasting works are fully possible in urban areas
- Rock blasting opens new possibilities (creating space)
- An accurate planning and execution is a demand
- Modern techniques available
- But… very many prejudices

Very important questions:

- What is a damage?
- Cost of damage vs. Cost of project

Thx to Trafikverket, Nitro Consult, Skanska & Royex

Thank you!

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