

# Unified model for design of rock grouting

Swedish concept for pre-grouting of infrastructure tunnels

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# Unified model for design of rock grouting

Aim:

- Unified model/structure for design of pre-grouting of infrastructure tunnels in Sweden

Goal:

- More effective grouting process
- Set a standard that at least can be expected



# Involvement of Industry

- Webinarium
- Work-shop
- Web-survey
- Presentations for the industry
- Sub-projects open for the industry
- Web-information
- Remittance

# Work-shop

Discussion regarding grouting activities and if they should be standardized, design or contractor issue

<b>Activity</b>	<b>Standardised</b>	<b>Design</b>	<b>Contractor</b>
Fan geometry			
Probe holes			
Grout characteristics			
Grout			
Material for grouting			
Equipment			
Performance			
Stop criteria			
Complementary holes			
Control performance			
Control sealing			

# Sub-projects

- Open for bids from the Industry
- In total around ten bids with participation from academic, contractors and consultancy
- Three different sub-projects:
  - Characterisation&Design
  - Technical Specifications
  - Contract and plan for Payment

# Characterisation & Design

Develop design categories (PK) based on:

- Rock groups

Rock group	Characteristics	Example of rock type and tectonics	Conceptual fracture system and water-bearing fractures
1	Low to moderate conductive rock mass with flow restrictions mainly due to limited fracture connectivity	Granite with low grade of brittle tectonic impact. Gneiss with low grade of brittle tectonic impact, and high grade of ductile deformation.	
2	Low to moderate conductive rock mass with flow restrictions mainly due to fracture filling/clay	Transformed/ brecciated granite. Schist and amphibolites, shales or foliated gneiss.	
3	Moderate to high conductive rock mass with well-connected fracture system with few flow restrictions	Shallow rock mass. Rock mass with high number of rock mass contacts and/or weakness zones without significant clay content.	

- Environmental demands
- Grouting difficulty

# Characterisation & Design

## Design categories:

Classification of Design category

	Low demands >0,25 l/min, 100 m x depth	Fair demands 0,15-0,25 l/min, 100 m x depth	High demands 0,10-0,15 l/min, 100 m x depth	Very high demands <0,10 l/min, 100 m x depth
Rock group 1	Design category 1		Design category 2	Design category 3
Rock group 2				
Rock group 3				

Adjustment of Design category regarding grouting difficulty

		Required sealing efficiency		
		< 90 %	90-99 %	>99 %
Hydraulic conductivity in the grouted zone $K_{inj}$ [m/s]	$>10^{-7}$ m/s	Ev. reduce the Design category		
	$10^{-7}$ - $10^{-8}$ m/s			Ev. increase the Design category
	$<10^{-8}$ m/s			

# Characterisation&Design

- Design Category 1: Design shall mainly be based on experience and there are pre-determined fan-layout that can be used.
- Design Category 2: Design is partly based on experience and there are standardised examples which shall be check by designer
- Design Category 3: The design shall be done by project specific design.



# Characterisation&Design

The design categories are guideline for determining:

- Extent of investigations
- Level of analysis in design
- Level of monitoring and follow-up

Develop design categories (PK) based on:

- Continuously up-dated through project phases
- Base for Grouting classes in the Construction phase

# Technical Specifications

- Transform the design into tender, contract and building documents
- Integrated into the *Swedish guidance for building and civil engineering works and building services contracts (AMA-system)*

# Technical Specifications

Example of subjects that are included:

- A minimum grout hole diameter
- Description of hole cleaning after drilling
- Requirements on packers
- Installation depth for packers
- Grouting sequence
- Requirements on grouting equipment
- Control of grouting characteristics

# Contract and Payment

- Performance contracts
- Fair risk distribution
- Up-date of the existing guideline regarding bill of quantities (MER-anläggning)
- Payment of time??

# Contract and Payment

## Payment of time

- On-going work
- Based on well-defined prognosis of Grouting classes
- Shall as well be a class for “unforeseen events” that is priced separately

# Implementation

- The design process is described in a "handbook"
- Standard text for technical specifications will form base for up-dating of the Swedish guidance (AMA-anläggning)
- The advices for technical specifications will form base for up-dating of the advising guidelines (RA-anläggning)
- The payment forms will form base for an up-date guideline regarding bill of quantities (MER-anläggning)

