Icelandic Tunnelling Society
May 4th 2015

Rock Mass Grouting

Presented by Chief Scientist/Professor
Eivind Grøv
SINTEF/NTNU
Rock Mass Grouting

SOME MAIN ASPECTS OF THE PRESENTATION:

- Tight Enough For Its Purpose!
- Water Control - Not Water Proofing!
- Pre-excavation Grouting!
- Prevent - Not Cure!

Photo: BAH
Rock Mass Grouting

Tunnelling accidents, as air traffic accidents, a chain of non-complying incidents that in a chain accumulate to a fatal accident.
Rock Mass Grouting

Water seepage into rock tunnels constitute non-complying incidents too.

How can we control water inflow like these??

And what would the consequences of non-compliance be??
Rock Mass Grouting

Hard rock environment

- The Scandinavian host rock varies from poor to extremely good rock.
- Folding, faulting and high tectonic stresses influence the stability in tunnels.
- Weakness zones can exhibit great variation in quality, Q-values from extremely poor to good.
- The width of such zones may vary from a few centimeters to tens of meters.
- The CHALLENGE: to deal with a frequently changing ground and ground water conditions.

It is typical Hard Rock, but not necessarily “Good Rock”
In previous hydropower tunnelling projects water inflow was a "plus", few, if any mentioned environmental impacts.

The construction of the Lieråsen tunnel 30 years ago drained a sumpy area to become valuable land for a new housing complex.

The Romeriksporten tunnel in late 90’es faced public, political, environmental and technical focus on a scale never experienced before.

The unfortunate affair at Romeriksporten triggered a new approach to water control in Norwegian tunnelling.
Rock Mass Grouting
Publications released recently

Publications issued by the Norwegian Tunnelling Society (affiliated with ITA)
Download free of charge at www.tunnel.no
Rock Mass Grouting

Purpose of these publications

- Water control according to the pre-grouting concept “prevention is better than cure”
- Focus has shifted to environmental concern rather than practical tunnelling aspects
- Technical lessons have been learned
- Demonstrate and document Norwegian experiences
- Provide assistance to the industry to reach a best practice approach
- Experiences believed to benefit tunnelling projects elsewhere
## Rock Mass Grouting

Check list for rock mass grouting design and execution

**Handbook on Rock Mass Grouting from NFF**
# Rock Mass Grouting

## Key issues:
- Understand the circumstances
- Identify a strategy
- Make a plan and prepare for it

### A. Surroundings and the rock cavern
- Ground conditions
- Conductivity of the ground
- Application
- Buildings
- Nearby underground installations
- Objectives
- Waterways
- Influence area
- Functional requirements
- Biotopes
- Sensitivity

### B. The bedrock
- Geology
  - Jointing
  - Tensions
  - Filling of fissures
  - Rock type
- Hydrogeology
  - Water table
  - Water flow in the rock
  - Chemical properties

### C. Grouting strategy – systematic vs. grouting as deemed necessary
- Geometry of grout cover
  - Penetration depth
  - Length
  - Number of holes
  - Overlapping
- Grouting agent
  - Materials selection
  - w/c ratio
  - Hardening
  - Admixtures
- Stop criteria
  - Volume
  - Pressure
  - Migrating leaks
# Rock Mass Grouting

## Key issues:
- Choose right equipment, Follow-up
- Document
- Fulfilling requirements
- Modify if necessary

## D. Execution

<table>
<thead>
<tr>
<th>Equipment</th>
<th>Grouting agent</th>
<th>Grouting crew</th>
</tr>
</thead>
<tbody>
<tr>
<td>- Mixer and agitator</td>
<td>- Supplier</td>
<td>- Experience</td>
</tr>
<tr>
<td>- Hoses and couplings</td>
<td>- Delivery plan</td>
<td>- Organisation</td>
</tr>
<tr>
<td>- Rods and packers</td>
<td></td>
<td>- Contingency plan</td>
</tr>
<tr>
<td>- Communication</td>
<td></td>
<td>- Risk analysis</td>
</tr>
</tbody>
</table>

## E. Documentation

<table>
<thead>
<tr>
<th>Drilling report</th>
<th>Grouting report</th>
<th>Quality</th>
</tr>
</thead>
<tbody>
<tr>
<td>- Length</td>
<td>- Amount per hole</td>
<td>- Stability</td>
</tr>
<tr>
<td>- Angular deviation</td>
<td>- Standing pressure</td>
<td>- Setting</td>
</tr>
<tr>
<td>- Inflow per hole</td>
<td>- Recipe(s)</td>
<td>- w/c ratio</td>
</tr>
<tr>
<td>- Special conditions</td>
<td>- Migrating leaks</td>
<td>- Storage time</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- Cement quality</td>
</tr>
</tbody>
</table>

## F. Results

<table>
<thead>
<tr>
<th>Geology</th>
<th>Documentation of execution</th>
<th>Documentation of quality</th>
</tr>
</thead>
<tbody>
<tr>
<td>Inflow measurements</td>
<td></td>
<td>Post-excavation grouting</td>
</tr>
<tr>
<td>Groundwater level</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Damage to environment</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Waterproofing</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

---

Image: SINTEF Building and Infrastructure
Rock Mass Grouting

Dealing with water has been and still is an issue of great concern in tunnelling, also world wide.

Conflicts arise from such as:

- Malfunctioning of tunnel, excessive water inflow
- Mishappenings, settlements, lost GW
- Misunderstanding of grouting concept
- Water tightness defects
- During construction and after completion
Rock Mass Grouting

One example not to repeat!!

- Boring for SSDS started in ’94, water inflow not considered
- But started right away
- JV had no experience with pre-grouting
- TBM's not equipped
- Contract did not hold reimbursement rules
- Dispute on responsibility
- In ’96 the JV was kicked out
- replacement engaged
Rock Mass Grouting
Why water control?

There are various requirements to an underground project, one might be to produce a “dry tunnel”

But why?

- Prevent an adverse internal environment in the tunnel, during construction and operation
- Prevent unacceptable impact on the external, surrounding environment
- Maintain hydrodynamic containment

And what is a “dry” tunnel?
Rock Mass Grouting

Drained concept(pregrouted):
- Temporaily prior to placing a lining
- Permanently in an unlined concept

Reduction of gradient at tunnel periphery
Rock Mass Grouting
Consequences of ground water lowering

- Disturbing existing biotypes,
  - flora and fauna might be sensitive to changes in groundwater conditions,
  - but
  - new species may show up that are better fit to a new situation (evolution)

- Draining of natural lakes and ponds in recreational areas
- Pore pressure reduction in soil deposits causing settlements of buildings and surface structures
- Lost containment could lead to leakage of stored products, i.e. contamination
- Consequences could be self-healing to none-mitigative
Rock Mass Grouting
Normal requirements to maximum inflow (Norway)

- A maximum inflow of 30 l/min/100m is used in e.g. sub-sea tunnels or elsewhere with no specific requirements.
- 2 l/min/100m in particular areas where sensitive objects can be found above the tunnel.
- Various requirements may apply for different sections of a tunnel pending on the local consequences of groundwater lowering.
# Rock Mass Grouting

<table>
<thead>
<tr>
<th>Project</th>
<th>Type of tunnel</th>
<th>Length of tunnel</th>
<th>Limit Residual Inflow Rate (LRIR) L/min/100m</th>
<th>Final L/min/100m</th>
</tr>
</thead>
<tbody>
<tr>
<td>T-baneringen</td>
<td>Metro</td>
<td>1,7 km</td>
<td>7 – 10</td>
<td>&lt; 7-10</td>
</tr>
<tr>
<td>Jong-Asker</td>
<td>Railway</td>
<td>4,5 km</td>
<td>4 – 16</td>
<td>2,5</td>
</tr>
<tr>
<td>Tåsen Tunnel</td>
<td>Highway</td>
<td>0,9 km</td>
<td>10</td>
<td>13</td>
</tr>
<tr>
<td>Svartdal Tunnel</td>
<td>Highway</td>
<td>1,5 km</td>
<td>5</td>
<td>&lt; 5</td>
</tr>
<tr>
<td>Storhaug Tunnel</td>
<td>Highway</td>
<td>1,25 km</td>
<td>3 – 10</td>
<td>1,6</td>
</tr>
<tr>
<td>Lysaker/ Sandvika</td>
<td>Railway</td>
<td>5,5 km</td>
<td>4</td>
<td>&lt; 4</td>
</tr>
<tr>
<td>Eiksfjord Tunnel</td>
<td>Subsea</td>
<td>7,7 km</td>
<td>30</td>
<td>&lt; 30</td>
</tr>
<tr>
<td>Oslofjord Tunnel</td>
<td>Subsea</td>
<td>7,3 km</td>
<td>30</td>
<td>&lt; 30</td>
</tr>
</tbody>
</table>
Rock Mass Grouting

Inflow Rate Achieved and Grout Take for Pre-grouted Land-based Tunnels
Rock Mass Grouting
The impermeable nature of the rock mass

The actual permeability of the rock mass and associated discontinuities may vary from 10-5 m/sec to 10-12 m/sec.

The rock mass is neither homogenous nor continuous, but suffering:
- Cracks and joints
- Weaknesses
- Weathering

- The permeability of rock mass may be in the range of 10-7 to 10-9 m/sec.
- A typical jointed aquifer, water occurs on the most permeable discontinuities.
- The most conductive zones must be identified and treated.
- Prevent the tunnel imposing an adverse situation in the ground-water regime.
Rock Mass Grouting

Definition of rock mass grouting

“the introduction of a material under pressure into the ground or a structure with the goal of waterproofing and consolidating voids, cracks and porosity” quoted from Ola Woldmo

Should be ”sealing off” rather than ”water proofing”
Rock Mass Grouting

Any particular properties that may govern the rock mass grouting?

- Minimum stress component, $\sigma_3$
- Permeability coefficient
- Joint frequency, volumetric joint number, RQD, Jn (several ways of addressing jointing)
- E-modulus and UCS
- Lugeon values
Rock Mass Grouting
Basic aspects in water control

- Rock mass is often a sufficient barrier (in general)
- Impermeabilization by grouting (match project specifications)
- Pre-grouting is dominant to post-grouting (in Norway)
- Membrane lining is used in rare occasions (in Norway)
- Re-infiltration is an option (unless no other choice works)
- A drained concept applies (in general)
Rock Mass Grouting

Post-grouting behind tunnel face pros & cons

• Chasing water from place to place
• Normally relative expensive chemical resins are used, also cement based
• Specialized teams are employed (not always)
• Time consuming and difficult to achieve success
• Limited impact on tunnel advance
• Reaches in general inflow criteria

Pre-injection is far more effective than post injection! (10 to 50 times less expensive to stop water ingress)
Rock Mass Grouting

Drained concept

- Excessive water is not allowed to build up behind support
- Support measures not designed to take the hydrostatic load
- Controlled handling of water, collection and discharge
- Inner lining to e.g. prevent water entering into the traffic area
- Inner lining does not interact with the tunnel support
- Number of solutions from membranes to pre-cast segments
Rock Mass Grouting
Pre-excitation analyses

- Empirical analysis, many places may have a comprehensive data base from previous projects.
- Analytical formulas developed, back-calculating a number of cases.
- Numerical modelling (2D & 3D) can be applied to simulate influence areas.
- Sensitivity analysis are the modern tool.
Rock Mass Grouting

Ground water balance

- There might be various indicators for assessing the influence of tunnelling on the GW.
- GW balance is a term of increased focus for:
  - determination of inflow requirements
  - and follow-up and monitoring of inflow
- GW balance may be limited to natural changes
- The inflow can be defined by the level at which GW balance is restored
- A “Ground water law” has been proposed saying that: -residual flow < 5-15% of the mean annual flow from the catchment area
Rock Mass Grouting
Aspects of a grouting strategy

- Evaluate the effect of inflow criteria
- Identify conductive zones in rock mass
- Aim at completing grouting after 1 round
- Focus on a limited area around the opening
- Choose grout type, mix design, pressure & grout hole pattern
- Include additives to custom design the properties of the grout
- Monitor inflow, evaluate modifications
- Integrate the grouting in the support system
# Rock Mass Grouting

## Aspects of a grouting strategy

<table>
<thead>
<tr>
<th>Rock cover</th>
<th>Max grout pressure in holes in roof &amp; walls</th>
<th>Max grout pressure in invert holes</th>
</tr>
</thead>
<tbody>
<tr>
<td>0 – 5m</td>
<td>20bar</td>
<td>30bar</td>
</tr>
<tr>
<td>5 – 15m</td>
<td>40bar</td>
<td>60bar</td>
</tr>
<tr>
<td>&gt;15m</td>
<td>100bar</td>
<td>100bar</td>
</tr>
</tbody>
</table>
Rock Mass Grouting
Various types of cement based grout

Injection into cracks = 3 x cement particle size

Urban tunneling require injection down towards 0.02 mm cracks
Rock Mass Grouting

Various types of cement based grout

Urban tunneling requires injection down towards 0,02 mm cracks

Practical test; use peas, marbles and golf balls, pour it into a mug of water and try to squeeze it down a narrow funnel.
Rock Mass Grouting

By Ordinary Portland Cement;

- Substantial bleeding, low Blaine value, high $D_{95}$ and slow setting.
- Limitations in OPC penetration compensated by excessive drilling and a very high grout pressure.
- OPC may be modified by adding Silica Slurry to the mix, but this will only reduce bleeding and will not have any significant effect on penetration or setting time properties.
- Material cost of OPC is 20 % of the cost of MC
- Total cost of drilling and material consumption will be in the same range as for MC.
- Cycle time would be 20 – 50 % longer than for MC.
Rock Mass Grouting

By Micro Cement;

\- No bleeding, medium Blaine value, low $D_{95}$ and fast setting. Stable penetrates into cracks 0.03 mm (Blaine 650).

\- Stop criteria; 1) reaching max. grout pressure of e.g. 100 bar or 2) consuming a grout volume of max. e.g. 1500 kg per hole

\- Accelerate by alkali free accelerator to the grout line.
Rock Mass Grouting

By Colloidal Silica:

- Is a valuable supplement to cement based grout.
- CS is a liquid mineral based grouting material and is different to micro silica slurry.
- It is two components with a viscosity like water and may be accelerated to set in the range of 1 – 60 minutes, it has long term stability and durability and will penetrate all fissures with openings that may cause water inflow.
- SC cost 300 - 400 % of MC but volumes will substantially be reduced compared to MC.
**Rock Mass Grouting**

Limit Residual Inflow Rate (LRIR)

- Inflow rates below 10 l/min/100m adds 50–70% on the excavation cost
- Time/cost related to grouting is not linear function to LRIR
- Excavation rate reduced by 10-60% by systematic probe drilling and pre-grouting pending on LRIR

As a rule of thumb:

- 2 – 15 liters/minute/100m => systematic pre-grouting
- > 15 liters/minute/100m => pre-grouting initiated by measured water inflow in probe holes (on demand)
Rock Mass Grouting

Key Performance Indicators for water inflow control in tunnels
Rock Mass Grouting
Results from a research programme

- Standardized, systematic grouting is most advantageous for ground water control and also for the excavation cycle.
- Increased drilling capacity allow a greater amount of holes for optimal grouting.
- Superplastizers and silica additives increase the penetrability and pumpability for grouting.
- Grouting pressure up to 100 bars yields better penetrability and grouting capacity.
- Reduce w/c ratios to improve quality of the grout, and stable cement grout → micro-cement $d_{\text{max}} < 20\mu\text{m}$ & 0 bleeding.
- The pre-grouting efforts improved the rock mass stability (the latter being also stated by Barton et. al. in 2002).
Rock Mass Grouting
Hydrodynamic containment

- Unlined caverns at shallow depth have been used for "Storage" to restrict product leakage
- Tunnelling may create a draw-down which could lead to a situation where: Internal pressure > GW pressure
- Specification: Water pressure shall be 2bar higher than internal pressure
- To obtain a specified GW level/pressure:
  - pre-grouting of the rock mass
  - water injection to maintain the GW level
Rock Mass Grouting
Monitoring and follow-up

- Pre-construction assessment can be made, working procedures can be established
- Monitoring is needed to document the effect on the ground water regime:
  - at surface before construction
  - at the tunnel face from probe holes
  - of water inflow to the tunnel
  - at surface during construction
Rock Mass Grouting

Hard facts HATS 2A:
- 21km tunnels, inkl. 4,5 km sub sea, X-section appr. 20m²
- Depth 70-160m, 10 vertical shafts, ca. 900' m³ solid rock
- Underneath HK Skyline, reclaimed land, extremely difficult situation & a negative history
- Sewage tunnel, concrete permanent lining

State-of-the-art experience and practice of relevant overseas projects (including projects in Scandinavian countries) on deep hard rock tunnelling below sea level
Rock Mass Grouting

Rock mass grouting before final concrete lining secures:

1. Ground water level is unaffected by underground works
2. Observed ground water lowering is not imposing settlements
3. Efficient means are available and applied if required

<table>
<thead>
<tr>
<th>Inflow Measured from Probe Hole(s) (l/min)</th>
<th>Limit of Residual Inflow as given in Table 508.1 (l/min/100m)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>15</td>
</tr>
<tr>
<td>From a single hole not less than 20m long</td>
<td>&gt;1</td>
</tr>
<tr>
<td>From two to four holes each not less than 20m long</td>
<td>&gt;3</td>
</tr>
</tbody>
</table>
Rock Mass Grouting

Lugeon-values for all rock types, specified as outside and inside weakness zones and their influence areas
Rock Mass Grouting

Connection between residual inflow and target

<table>
<thead>
<tr>
<th>Tunnel Chainage</th>
<th>Target Residual Inflow (l/m/100m)</th>
<th>Residual Inflow (l/m/100m)</th>
<th>Duration Weeks</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>&lt;5</td>
<td>5-15</td>
<td>15-30</td>
</tr>
<tr>
<td>J 0</td>
<td>1800</td>
<td>624</td>
<td>104</td>
</tr>
<tr>
<td>J 1800</td>
<td>2700</td>
<td>61</td>
<td>10.5</td>
</tr>
<tr>
<td>J 2700</td>
<td>3200</td>
<td>624</td>
<td>104</td>
</tr>
<tr>
<td>K 0</td>
<td>800</td>
<td>624</td>
<td>104</td>
</tr>
<tr>
<td>K 800</td>
<td>1100</td>
<td>90</td>
<td>15</td>
</tr>
<tr>
<td>K 1100</td>
<td>2500</td>
<td>258</td>
<td>86</td>
</tr>
<tr>
<td>K 2500</td>
<td>4300</td>
<td>39</td>
<td>13</td>
</tr>
<tr>
<td>L 0</td>
<td>4400</td>
<td>624</td>
<td>104</td>
</tr>
<tr>
<td>L 4400</td>
<td>4600</td>
<td>12</td>
<td>2</td>
</tr>
</tbody>
</table>
# Rock Mass Grouting

Introduction of the Grout Intensity Classes for the HATS project in Hong Kong

<table>
<thead>
<tr>
<th>Geology/situation</th>
<th>Klk, No fault</th>
<th>Klk Near fault</th>
<th>Klk High init. Inflow *</th>
<th>Fault/ CDG</th>
<th>Volcanic, No fault</th>
<th>Close to rock surface in shafts</th>
</tr>
</thead>
<tbody>
<tr>
<td>Confinement stress</td>
<td>Normal</td>
<td>Normal</td>
<td>May be poor</td>
<td>May be poor</td>
<td>Normal</td>
<td>Poor</td>
</tr>
<tr>
<td>Static water pressure, bar</td>
<td>150</td>
<td>150</td>
<td>150</td>
<td>150</td>
<td>150</td>
<td>50</td>
</tr>
<tr>
<td>≤ 5 l/min, 100 m</td>
<td>GIC III C</td>
<td>GIC IV C + E</td>
<td>GIC III+ A + C</td>
<td>GIC V D + E</td>
<td>GIC III C</td>
<td>GIC IV D</td>
</tr>
<tr>
<td>5 - 15 l/min, 100 m</td>
<td>GIC II B</td>
<td>GIC III C</td>
<td>GIC III+ A + B</td>
<td>GIC V D + E</td>
<td>GIC III C</td>
<td>GIC IV D</td>
</tr>
<tr>
<td>5 - 30 l/min, 100 m</td>
<td>GIC II A</td>
<td>GIC III B</td>
<td>GIC II+ A + A</td>
<td>GIC V D + C</td>
<td>GIC II B</td>
<td>N.A.</td>
</tr>
</tbody>
</table>
### Rock Mass Grouting

More details on the Grout Intensity Classes for the HATS project in Hong Kong

<table>
<thead>
<tr>
<th>Concept</th>
<th>Required spacing</th>
<th>Overlap, m</th>
<th>Packer depth</th>
<th>Grout type and W/C ratio</th>
<th>Stop criteria</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Pressure (net)</td>
</tr>
<tr>
<td>A</td>
<td>3.0 m</td>
<td>5 m</td>
<td>2 m</td>
<td>Cement, 0.9 – 0.5</td>
<td>50-70 bar</td>
</tr>
<tr>
<td>B</td>
<td>2.0 m</td>
<td>5 m</td>
<td>2 m</td>
<td>Cement, 0.9 – 0.5</td>
<td>50-70 bar</td>
</tr>
<tr>
<td>C</td>
<td>1.5 m</td>
<td>5 m</td>
<td>2 m</td>
<td>Cement, 0.9+ stab</td>
<td>50-70 bar</td>
</tr>
<tr>
<td>D</td>
<td>1.5</td>
<td>100 %</td>
<td>3 m*</td>
<td>Cement</td>
<td>30-40 bar</td>
</tr>
<tr>
<td>E</td>
<td>1.5</td>
<td>varied</td>
<td>3 m*</td>
<td>CS</td>
<td>30-40 bar</td>
</tr>
</tbody>
</table>
Rock Mass Grouting
Rock Mass Grouting

Excerpt from Technical Specifications
Tech.Specs = key to success

- Based on mikro-cement
  - Blaine value min. 625m2/kg
  - Particle size 95% to pass 20micron
- Colloidal silica may be instructed by Owner, OPC only seldom
- Admixture to control hardening (alkali-free)
- W/C ratio = 0.5-1.2, or according to suppliers recommendation
- Requirement on allowable bleeding
- Moderate to high stop criteria based on grout pressure, pumps shall handle hydro static pressure + 75 bar
- Stop-criteria on grout consume
Rock Mass Grouting

PRE-GROUTING "PREVENT NOT CURE"

The main advantages with this concept:

- It provides a flexible approach.
- It utilizes capability of the rock mass, impervious characteristic.
- It is cost effective.
- It reduces the construction time.
- It fulfils the requirement for water control in urban tunneling, focus practicality of water pumping during excavation.
- It provides full documentation of all activities.
- Follow-up and monitoring is an important concluding aspect.
Rock Mass Grouting

Do remember:
- Water control by Pre-grouting is not a rocket science!
- Rather basic methodology knowledge
- Skilled personnel
- Good equipment
- Right materials
- Lots of patience
- Hard work
Rock Mass Grouting

NORDIC GROUTING SEMINAR 2016
8th in row
Oslo, Radisson Blu Scandinavia Hotel
Week 37, 26 – 27 September 2016

State of the art - where does the grouting develop – future development
Basert på tilbakemeldinger og ønsker fra bransjen og tunnelmiljøet i Norge ser NFF at det er behov for at man i tunnelbransjen innfører et kompetanserettet kurs innenfor berginjeksjon og injeksjonsteknikk. Injeksjonsteknikk i Norge er en typisk erfaringsbasert arbeidsoppgave og med varierende fremgangsmåter for å nå det samme målet. Av noen er det gitt betegnelsen 'svartemagi' mens andre definérer det som 'håndverk', der man med dyktighet oppnår de krav til tetthet som er stilt. Målet med dette kompetanserettede kurset er å etablere en større forutsigbarhet knyttet til gjennomføring av berginjeksjon for underjordsanlegg.

Innenfor temaet injeksjonsteknikk foregår kontinuerlig utvikling av utstyr, utførelse, materialtilgjengelighet etc. Gjennom et kompetanserettet kurs skal det undervises i det som er å anse som dagens kunnskapsnivå innen injeksjonsteknikk for dørigjennom å bedre forståelsen hos alle involverte parter i dette arbeidet. Kurset henvender seg til alle som deltar i injeksjonsarbeider, enten på prosjekteringstid, hos leverandør, i det utførende eller som kontroller. Med felles forståelse av arbeidsoppgaven injeksjonsteknikk, eller berginjeksjon, stiller bransjen bedre rustet til å kunne oppnå de krav som samfunnet setter som ramme-betingelser for våre oppgaver.

Som grunnlagsdokument for kurset vil det benyttes den siste versjonen av NFF Håndbok nr. 06 datert juli 2010, 'Praktisk berginjeksjon for underjordsanlegg'. Dette er en dokumentasjon på det som anses å være alminnelig og normal berginjeksjon i Norge i dag. I tillegg lages forelesningsmateriell som også vil bli utdelt ved kurset og som inngår i kursets pensum.

Kurset er planlagt over 3 dager og skal gi; en grunnleggende teoretisk basis, forståelse av geologiske betingelser, kunnskap om materialer og utstyr, strategi og dokumentasjon av utført injeksjonsarbeid. Dette er basert på totalt 2,5 dager med forelesninger, enkle praktiske klasseromdemonstrasjoner, eksempler og diskusjoner. Kurset avsluttes med en skriftlig 3 timers eksamen. Bestått eksamen gir kursbevis. Det er begrenset antall plasser på kurset.

**Kurskomité og foreleser:**
John Ivar Fagermo, AF Gruppen
Erik Frogner, AF Gruppen
Eivind Grøv, SINTEF
Hans-Olav Hognestad, BASF
Alf Kveen, Statens vegvesen Vegdirektoratet
Hanne Wiig Sagen, Jernbaneverket
Ola Woldmo, Normet Norway AS
Rock Mass Grouting

TIGHT (4 year research program involving companies from Norway, Sweden, Singapore and Korea)

= True Improvement in Grouting High pressure Technology for tunneling, or

Development of high pressure rock mass grouting to seal off tunnels and caverns

High pressure grouting is in focus
Rock Mass Grouting
Concluding remark!

"TIGHT ENOUGH FOR ITS PURPOSE"