Winter concreting using hydronic heating –
Full-scale field trial of rock tower foundations

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Sustainable Cold Climate Technology

**ColdTech project**

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Funding: approx. 110 mil. NOK

Personal: approx. 60 people actively involved
**Coldtech - Primary Areas of Research Profiling**

**WP1: Wind Protection Design and Performance**

**WP2: Sea Ice Properties and Loads on Structures**

**WP3: Atmospheric Icing**

**WP4: Applied Arctic Technology**

- Oil in ice
- Iceloads on dams
- Solar cell-power in northern areas
Background - Norwegian Power Grid development plans

- Population growth in the big cities, the need to upgrade old facilities, increased renewable energy production and industrial growth are among main drivers
- Expected investment level of NOK 5-7 billion each year for the next ten years.
- Due to constraints related to reindeer herding and bird hatching a lot of the construction work has to be carried out during winter season
- Casting of rock tower foundations is identified as one of the most challenging activities with respect to cold climate construction
Historic boost for power system of the future

On 1 October, Statnett presented the 2015 Grid Development Plan. The plan describes development trends and anticipated main grid investments going forward. “We have launched unprecedented efforts to develop and upgrade our power system,” says Håkon Borgen, Executive Vice President of Technology and Development at Statnett.

Population growth in the big cities, the need to upgrade old facilities, increased renewable energy production and industrial growth are among the main reasons Statnett is about to enter a period with a historically high investment level. Statnett has also started to construct two international interconnectors to Germany and the UK, which will contribute to increased value creation and more use of renewable energy in Norway and the rest of Europe.
Main challenges

How to cast rock foundations with sufficient quality when:

- Bedrock temperature is low (0 to -10 °C)
- Air temperature is below 0 °C (including wind and snowdrift)
- Long transports (helicopters, no roads, high in the mountains)
- Small concrete volumes and cross sections
- Limited time and access of equipment
Technical explanation of challenge?

- Reduced bond between rock bolts and bedrock
- Reduced strength and durability due to freezing of fresh concrete
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Frozen bedrock
Traditional heating/thawing from the top surface

Figure 2 Temperature plots showing temperature distribution from heating bedrock with initial temperature -2°C only from surface. a) after 2h heating, b) after 2 h cooling, and c) after 10 h cooling.
Example showing the effect of surface heating?

- Not effective!

*Figure 4* Temperature plots showing temperature distribution from heating bedrock from surface. Initial temperature -5°C. a) 6 hours into warming phase. b) 18 hours into warming phase. c) 40 hours into warming phase. d) 6 hours after warming. e) 18 hours after warming) 40 hours after warming.
Proposed Heating from the holes drilled for the rock bolts

- Very effective!

Figure 3. Temperature plots showing temperature distribution from heating bedrock with heat poles initial temperature -5°C. a) 6 hours into warming phase. b) 18 hours into warming phase. c) 40 hours into warming phase. d) 6 hours after warming. e) 18 hours after warming. f) 40 hours after warming.
The tested procedure

- Drilling of holes in frozen bedrock
The tested procedure

- Placing specially developed hydronic heating system in holes
- Isolation during heating
Numerical modelling had shown that heating for 36 hours was sufficient.
Full scale test with Heatwork ®

www.heatwork.com
Temperature measurements in the bedrock

Rock temperature measured at ~100 mm, 400 mm, 800 and 1500 mm. Filled with dry mortar.

Temperature measured on wood pole 100 mm, 400 mm, 800 mm and 1500 mm below surface during heating. On rock bolt after cooling.

Temperature measured rock bolt after heating 100 mm, 400 mm, 800 mm and 1500 mm.
Temperature measurements in the concrete foundation towers

- Close to footbolts
- Close to PERT - pipe
- Between PERT - pipes
- Away from PERT - Pipe
Figure 21 Thermocouple mounted to rockbolts (rebars) during grouting.
BM 180 – Heating of bedrock
Heating and monitoring
The weather during testing
Results – Heating of bedrock

[Graphs showing temperature changes over time for different depths and conditions]
Casting of concrete foundation towers
Results – Concrete foundation footing
Resultats – Concrete towers
Conclusion

- It is possible to cast concrete rock tower foundations with extremely good quality at ebrocl and air temperatures below -10°C.

- Use of hydronic heating secures extreme temperature control since there is no danger of overheating.

- The developed hydronic heating system can be used for different size foundations to secure optimum hydration for concrete grouting and concrete.
Thank you for the attention!

For more information about the project, see http://ndat.no/vs/

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