High pressure and temperature grouts

GEORG – General Assembly Meeting 21-05-2010
Partners:

• Mannvit Engineering
• Reykjavik University
• Innovation Center Iceland
• Icelandic GeoSurvey
Work plan – duration one year – 5 tasks:

1. Improved mix-design, material selection and testing of grout
2. Assessment of temperature and pressure conditions in boreholes
3. Testing of behavior of selected mixes at high pressure
4. Full-scale testing of selected mixes
5. Final report
Improved mix design, ...

Performed at 1 bar and 25 °C

Cements tested:
Icelandic Portland, Rapid Danish Portland, Blast furnace slag cement (Irish/Chinese), Dyckerhoff well cement, Norcem well cement, Danish White cement

Solid additives:
Fly ash, silica flour, bentonite, perlite

Admixtures:
Water reducing agents, retarders, plasticizers, viscosity modifying agents
Improved mix design, ...

Common mixture in Iceland (kg/m$^3$):
Cement (OPC): 717
Silica flour: 287
Bentonite: 17.9
Perlite: 14.3
Water: 575

Mixture used in IDDP in Krafla 2008/2009 (kg/m$^3$):
Cement (Dyckerhoff): 801
Silica flour: 534
Bentonite:
Perlite:
Water: 506

Example of mixture from this work (kg/m$^3$):
Cement (Norcem G): 757
Silica flour: 418
Bentonite: 18.9
Perlite: 15.1
Water: 560
Improved mix design, ...

Work done by Mannvit, testing program:

Density, flowability, flow stability, setting time, adiabatic heat development, bleeding, thermal expansion, compressive strength (1, 2, 7 and 28 days).
Improved mix design, ...
Work done by Mannvit, examples from testing Retarders with Icelandic cement

Adiabatic heat development

<table>
<thead>
<tr>
<th>Retarder dosage (kg/m³)</th>
<th>Setting time (hrs)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>23</td>
</tr>
<tr>
<td>1.5</td>
<td>30</td>
</tr>
<tr>
<td>3.0</td>
<td>40</td>
</tr>
</tbody>
</table>

High P and T grouts - 21-05-2010
Improved mix design, ...

Work done by Mannvit, examples from testing

Compressive strength development

![Graph showing compressive strength development over age.](image-url)
Improved mix design, ...

Work done by Mannvit, examples from testing

Compressive strength development

Difficult if not impossible to measure compressive strength of immature (young) grout, must rely on calculated values.
The results of this will be used in Task 2.
Improved mix design, ...

Work done by Mannvit, examples from testing
Flowability of grout
2 series – OPC Icelandic

No water reducer
no plasticizer

High dosage of water reducer
no plasticizer

Low dosage of water reducer
no plasticizer
Improved mix design, ...

Work done by Mannvit, examples from testing
Flowability of grout
3 series – rapid Danish cement with fly ash

Medium dosage of plasticizer – no stabilizer
Low dosage of plasticizer – high dosage of stabilizer
High dosage of plasticizer – low dosage of stabilizer
Improved mix design, ...

Work done by ICI, examples from testing

Yield value of different binders

![Graph showing yield value of different binders over time.]

Figure 1: Yield value of six different binders at a w/c-ratio of 0.80
Improved mix design, ...

Work done by ICI, examples from testing

Plastic viscosity of different binders

Figure 2: Plastic viscosity of six different binders at a w/c-ratio of 0.80
Assessment of T and P conditions in wells

Work done by Mannvit and ISOR, testing just underway:

Computer simulations on early age strength development in wells
Attempt to use a computer program HACON³

Measure strength development of well grouts at temperatures < 100 °C

Collect data from well, mainly temperature in wells before and after concreting
HE-51
Temperature, °C

Depth, m

24092008 03:43 before concreting
25092009 18:00 after concreting
26092008 08:52 after concreting

High P and T grouts - 21-05-2010
HE-51
Temperature, °C

Depth, m

- 30092008 11:00 before concreting
- 02102008 06:22 after concreting
Computer simulation, compressive strength

A simple example to show compressive strength development of “well grout” in a “well” with 130 °C hot bed rock

High P and T grouts - 21-05-2010
Compressive strength development at 20, 40 and 80 °C, data from IBRI
Testing of behavior of selected mixes at high pressure

Work done by ICI, testing just underway

• Rheo-microscope - Physica MCR 101
• P and T rheometer - the Modular Rheometer Series

Producer: Anton Paar Germany GmbH - Helmuth-Hirth-Str. 6, D-73760 Ostfildern, Germany-Europe
Applications

• Applies to “ordinary” grouts
  rheological properties best described as a Bingham fluid
  \[ \tau = \tau_0 + \mu \gamma \]
  reduce wait on cement
  reduce/eliminate bleeding

• High P and T grouts
  (at about 3.5 km depth: 220-250 bar and 450-500 °C)
  improve knowledge on high P and T grouts
  suggest mixture and dosages for high P and T grouts
  much more effect of T than P on rheological properties of grouts
  rheological properties still as a Bingham fluid
Casings in IDDP-1

- Surface casing Ø32½"
- Intermediate casing 1 Ø24½"
- Intermediate casing 2 Ø18⅝"
- Anchor casing Ø13⅝"
- Production casing Ø9⅝"

Bleeding from grout
Schematic explanation of damaged to casings due to expansion of vapor

1. Casing and concreting
2. Casing and concreting
3. Casing and concreting
4. Loss of grout into cracks
5. Bleeding water from grout
6. Concreting and sealing in a water pocket
7. Damaging of casing due to vapor expansion
Conclusions

Work underway, 1 bar and 25 °C work finished
We believe that we can improve the stability of ordinary grout
Possibly reduce wait on cement

Work at high P and T just started