2005 Tri-Service Infrastructure Systems Conference

Re-Energizing Engineering Excellence

State of the Art in Computer Monitoring and Analysis of Grouting

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The Old Way of Grouting

- Qualitative Design
  - Example: Depth of holes equal to height of dam
- Vertical Holes –
  - might or might not be appropriate depending on geology
- Unstable Grouts –
  - Typically neat cement grouts
- Pressures – Based on usually conservative rules of thumb
- Data Acquisition – Dipstick and Gauge Technology
- Data Recording - Inspector at each header manually recording and plotting grout take versus time with average pressure recorded.
Data Collection & Monitoring (2000)
Analysis (2000)

PROGRESS / ANALYSIS PROFILES
The New Way of Grouting

- Quantitative Design
  - Intensity of Grouting consistent with design assumptions and requirements
- Hole Orientation and Depth selected consistent with site geology
- Stable Grouts with multiple admixtures
- Pressures – Maximum safe pressure utilized
- Data Acquisition – Flowmeters and Pressure Transducers
- Data Recording – Computer Monitoring by experienced Engineer of Geologist
Advantages

- Measurement Accuracy Significantly Improved
- Real Time Data is obtained (2-10 seconds vs. 5-15 min.)
- Allows one to use higher pressures with confidence; Dilation and Lifting easily picked up on screen
- Formation Response to procedure changes (mix or pressure) are known immediately
- Accelerates the Work
- Reduces Inspection Manpower Requirements
- Permits reallocation of resources to analyze program results and recommend cost effective program modifications.
Curtain Total Costs

- Total Curtain Cost

- Conventional
  - Special Costs
  - Inspection Costs
  - Construction Costs

- Advanced
  - Special Costs
  - Inspection Costs
  - Construction Costs
Level 2 Technology

Key:
- Green circle: Automatically obtained by system
- Yellow circle: Obtained with moderate additional effort
- Red circle: Obtained with significant additional effort

Water Lugeon Value = 100

Sample Text File (CAGES Output):

Sample Progress/Analysis Profiles:

B-Line Section 4
Bays 1-11 20-40 ft

Lugeon Values
Grout Take (Liters)

Flow (liters/minute) vs. Time (minutes)

Gage Pressure (psi) vs. Time (minutes)

Apparent Lugeons (La) vs. Time (minutes)

Hole Behavior - High Lu

Automatically obtained by system

Obtained with moderate additional effort

Obtained with significant additional effort
The image contains a computer display of what appears to be a data analysis or monitoring software interface. The interface includes various charts, graphs, and data tables, which are typical of industrial or engineering software used for real-time monitoring and control.

### Table Content

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value 1</th>
<th>Value 2</th>
<th>Value 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Parameter A</td>
<td>123.45</td>
<td>67.89</td>
<td>34.56</td>
</tr>
<tr>
<td>Parameter B</td>
<td>98.76</td>
<td>23.45</td>
<td>56.78</td>
</tr>
<tr>
<td>Parameter C</td>
<td>45.67</td>
<td>78.90</td>
<td>12.34</td>
</tr>
</tbody>
</table>

### Chart Details

- **Graph 1**: Shows a trend line with data points indicating a decreasing trend over time.
- **Graph 2**: Displays a histogram with a normal distribution pattern.
- **Graph 3**: Contains a bar chart illustrating comparative data across different categories.

### Diagram Elements

- The interface includes various controls for adjusting settings and viewing different data sets.
- There are also indicators for real-time data updates and historical data reviews.

### Additional Observations

- The software seems to be part of a larger system, possibly related to process control or monitoring applications.
- The interface design is intuitive, allowing for easy navigation and data interpretation.

This detailed description should help in understanding the content and functionality of the software interface shown in the image.
Level 3 Technology

Key:
- Green circle: Automatically obtained by system
- Yellow circle: Obtained with moderate additional effort
- Red circle: Obtained with significant additional effort
- Lugeon Value < 6 = Purple
- 6 < Lugeon Value < 10 = Green
- 10 < Lugeon Value < 50 = Lt. Blue
- 50 < Lugeon Value < 75 = Yellow
- Lugeon Value > 75 = Red
Interactive Geology

- Logical organization of Geotechnical and Geological Data
- Electronic link between data
- Eliminates sorting through paper logs, photographs, lab test results, etc. to interpret conditions
• Typed boring logs and stick logs are inserted into AutoCAD file

• Detailed geologic profile generated

• Data is linked using Hyperlinks

Hot spot on Stick boring log links to view of drilling log
Red text on drilling logs indicates additional linked information.
Core Run ID links to photo of recovered sample
Comments links to photo of core box

In this case a tool drop and loss of water return was noted.
Test Section - Lugeon Values in Liston Creek

Primaries
- A-Line: 68
- B-Line: 45
- Tertiaries: 35

Secondaries
- (P & S Combined on A-Line): 26

Tertiaries
- A-Line: 23
McCook Reservoir - Grout Test

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Preliminary Intelligrout Drawing Update (updated 11/01/03)

Notes:

1. Update drawings are not record drawings. Information shown is preliminary based on work in progress and is subject to revision.

2. Efforts will be made to provide updated drawings on approximately a weekly basis.
Summary

- Computer monitoring and analysis of grouting has come of age as a reliable and effective tool for better faster and less expensive grouting.

- When combined with proper investigation, design, and contract mechanisms, real time data collection and analysis by a competent grouting engineer or geologist results in engineered grout curtains constructed with dependable predictable performance with virtually the same degree of confidence in quality as visible above ground construction.
Drain Outlets at Toe of Dam

Project Success
QUESTIONS

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