Foundation treatment (grout) for dam construction

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Introduction

- Definition of grout
  - Injection of a cement based material to fill cracks or clearance
    - Rock grouting: rock stabilization, impermeation
    - Chemical grouting: impermeation
    - Jet grouting: soil stabilization
    - Sleeve grouting: soil stabilization

- Grouting for dam construction
  - To improve geological characters of rock and/or soil at foundation area of dam with pressurized cement based material into the ground. And also to fill the clearance of structures injecting grout material
Type and purpose of grout

- Consolidation/Blanket grout
- Curtain grout
- Back fill grout
- Others
  - Joint grout
  - Contact grout
Curtain grout

A barrier produced by injection grout into a vertical zone in the foundation parallel to the dam centerline to reduce seep rates under dam.
Curtain/Consolidation (blanket) grout
**Back fill grout**

Filling any voids existing with cement grout or mortar, e.g., between a concrete tunnel lining and the surrounding rock.

**Other grout**

- Joint grout: Grout joint parts between concrete and concrete
- Contact grout: Grout for contact between existing concrete structure and steel pipe or new concrete structure
1. Stage grout

Stage grouting is conducting to permit treatment of various zones individually by grouting increasing depths successively after sealing the upper or lower zones. The effect of grout can be easily reviewed by subdividing the area to be grouted. One stage shall be normally 3 to 5m. The following methods are generally employed.

- Down stage (descending) method
- Up stage (ascending) method
Stage grout

Descending arrangement (Down stage grouting)

- Drilling
  - Setting up drilling machine & Preparation
  - Drilling (specified one stage only)
    - Washing bored hole
  - Packer setting up
  - Water pressure test
  - Grouting (No more stage)
  - Shifting drilling machine
  - Plugging grout hole

Next stage

- Grouting

Re-drilling

Ascending arrangement (Up stage grouting)

- Drilling
  - Setting up drilling machine & Preparation
  - Drilling (up to specified depth)
    - Washing bored hole
  - Packer setting up
  - Water pressure test
  - Grouting (No more stage)

Next stage

- Grouting

- Shifting drilling machine
  - Plugging grout hole
2. Lu(Lugeon) test

In order to measure permeability of dam foundation area, lugeon test shall be conducted. Lu(lugeon value) is water volume injected at 10kgf/cm² for 10 minutes per meter. The target Lu value after foundation treatment is generally 3 to 5.

<table>
<thead>
<tr>
<th>Stage</th>
<th>Pressure (bar)</th>
<th>Time duration of each step</th>
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<tbody>
<tr>
<td></td>
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<td>Pilot/Control hole</td>
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<tr>
<td>1&lt;sup&gt;st&lt;/sup&gt;</td>
<td>1→3→1</td>
<td>9 min.</td>
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<tr>
<td>2&lt;sup&gt;nd&lt;/sup&gt;</td>
<td>2→5→2</td>
<td>9 min.</td>
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<td>3&lt;sup&gt;rd&lt;/sup&gt;</td>
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<td>9 min.</td>
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<tr>
<td>4&lt;sup&gt;th&lt;/sup&gt;</td>
<td>2→5→7→5→2</td>
<td>9 min.</td>
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</table>
Lu-value = \(10 \times \frac{Q}{L \times P}\)

- **Q**: Injection volume (L/min.)
- **L**: Test length (m)
- **P**: Test pressure (kg/cm²)

In case \( h_1 > h_3 \)

- \( P = P_0 + \frac{(h_2 + h_3)}{10} \) (kg/cm²)

In case \( h_1 < h_3 \)

- \( P = P_0 + \frac{(h_2 + h_1)}{10} \) (kg/cm²)

- **P₀**: Pressure at manometer (kg/cm²)
- **h₁**: Depth of test (m)
- **h₂**: Manometer/Pressure gauge height (m)
- **h₃**: Ground water level (m)
Grout system

3. Grout

-Mix ratio
Based on Lu test result, the first mix ratio of grout shall be determined. Thin grout travels farther than thick grout. Therefore, it is generally to start with a thin mixture which is 4/1 or 5/1(W/C) mixing ratio. Then, the mixture shall be changed to thick proportion.

-Grout pressure
The maximum grout pressure shall be determined based on grout test result not exceeding the critical pressure of original ground.
SEQUENCE OF GROUT INJECTION AND CHANGE OF GROUT MIX PROPORTION

For 3m stage

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For CN

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<th>Ratio</th>
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LEGEND:

Q 2/1: Total grouting volume of certain mix proportion injected (liter)
(The suffix 2/1 indicates the mix proportion W/C)

P: Grouting pressure (kg/cm²)

N: Maximum allowable refusal pressure for grouting (kg/cm²)

q: Grout injection rate (liter/minute)

W/C: Mix proportion of grout in the weight ratio of water/cement.

SAMPLE
4. **Back fill/contact/joint grout**

The grout for filling purpose is not necessary to change the grout mixing ratio. And the grout shall be conducted with own grouting pressure not to damage the existing structure.
Evaluation of grout result

1. Producing lugeon map

Standard lugeon test or instant lugeon test shall be conducted before grouting at every stage. The result shall be showing on a map for evaluating grout effect. The map shall be produced every row (primarily, secondary……).

2. Producing grout intake map

Actual grout intake which is injected cement volume per meter shall be calculated and shown on a grout intake map for all grout. The map also shall be produced for every row.
3. Evaluation of grout

The results of lugeon map and grout intake map shall be evaluated. Lugeon value and grout intake is basically related. If a stage, where is high lugeon value, results low grout intake. The grout will be considered non-effective or fairer of grout. In this case, additional grout shall be conducted.

4. Check hole

Check hole shall be conducted for verifying the effect of grouting works. The grout is completed when the measured Lu value from check hole achieves the target Lu value.
### Lu map – Grout intake map

#### Lugeon Map

<table>
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<tr>
<th>Stage</th>
<th>P1</th>
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#### Cement intake Map

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**Legend:**

- 7 ≤ Lu ≤ 10
- 5 ≤ Lu ≤ 7
- 3 ≤ Lu ≤ 5
- 10 ≤ Lu > 15
- 15 ≤ Lu > 20
Grouting works in Dai Ninh Hydropower dam project

*Design quantity*

1. Consolidation grout : 41,750m, 7,407 stages
2. Curtain grout : 37,440m, 6,643 stages
3. Consolidation core drilling : 4,650m
   pilot and check hole
4. Curtain core drilling : 4,250m
   pilot and check hole
5. Exploratory drilling : 460m
6. Drain hole drilling : 1,370m
7. Relief well drilling : 4,630m
Typical layout of grout holes
Typical layout of grout holes
-Drilling-

Rotary drilling

Rotary drilling on stage

Rotary percussion drilling

Rotary percussion drilling

Drilling site & core
-Grouting-

Main plant

Sub plant

Flow meter

Manifold

Grouting

Packer & gas regulator
-Grouting site-
KOKEN PRODUCT
– for Dam Construction–

Anchoring

Drain hole drilling

Shaft drilling

Grouting