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

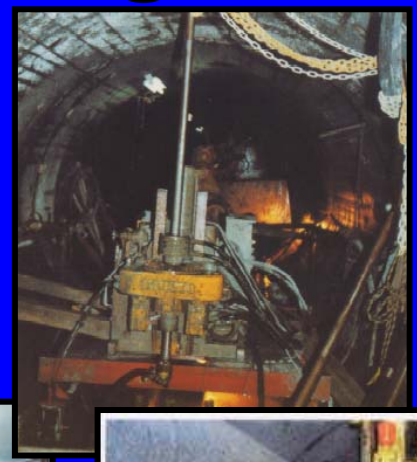
-Sleeve grouting : soil stabilization

- 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



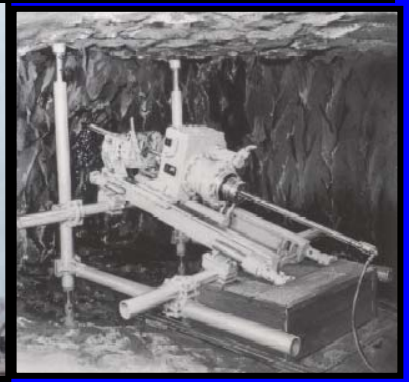
Curtain grout

Back fill grout

Others

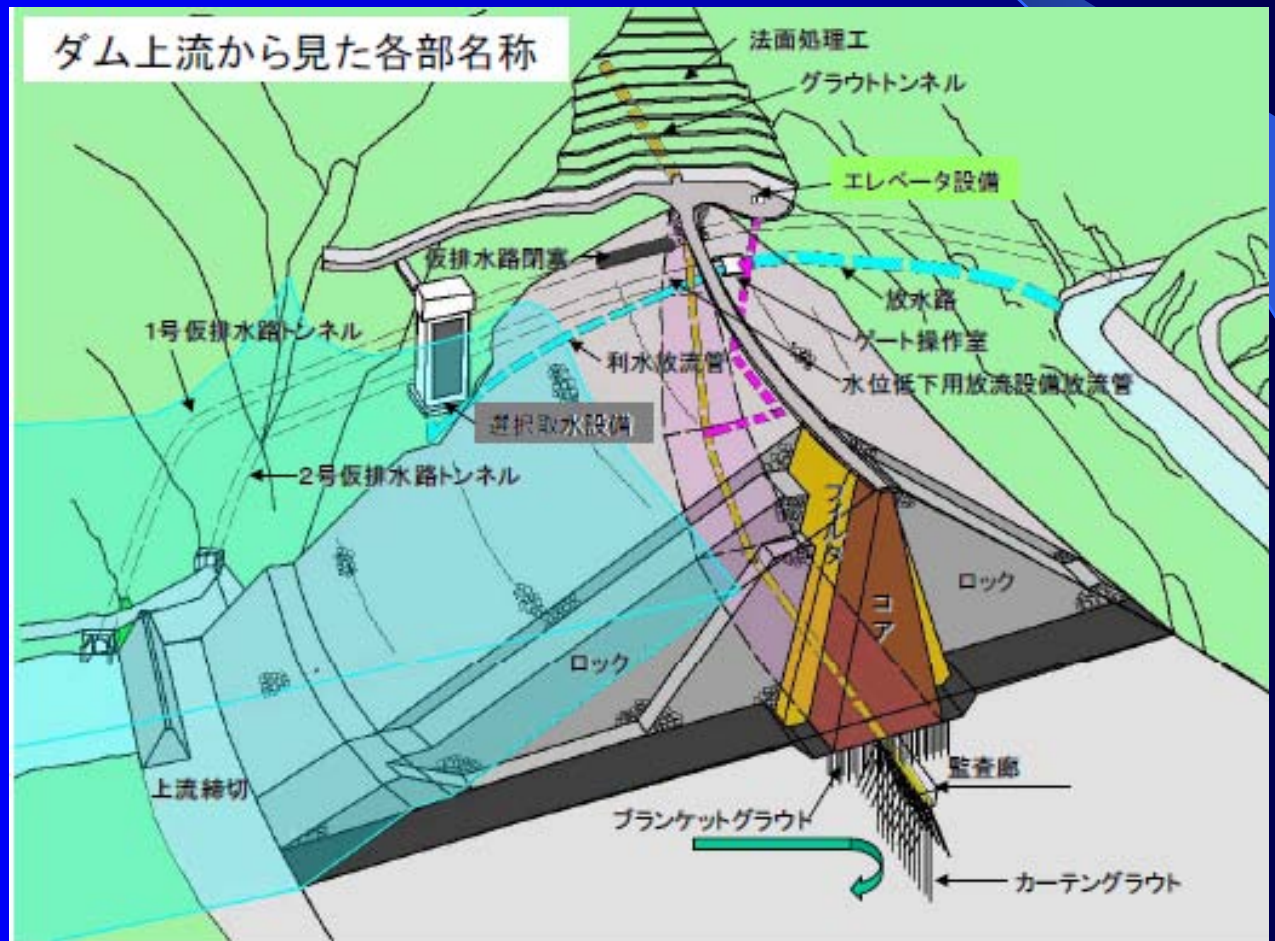
-Joint grout

-Contact grout

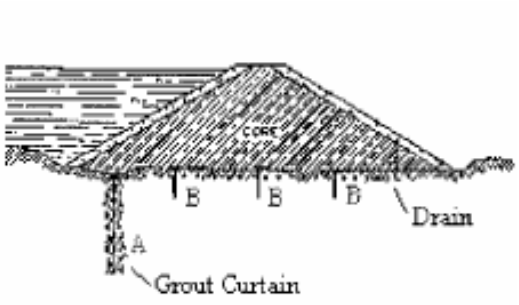


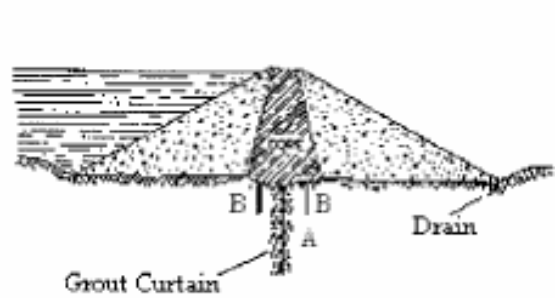
Curtain grout

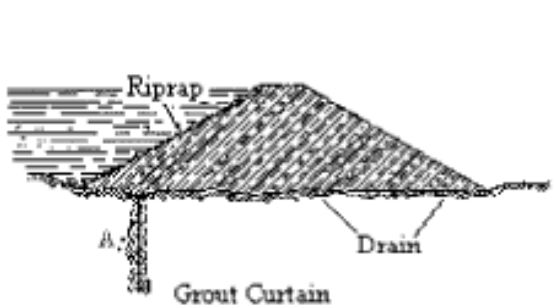
A barrier produced by injection grout into a vertical zone in the foundation parallel to the dam centerline to reduce seep rates under dam.

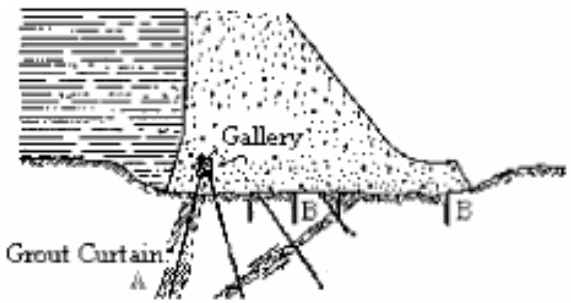


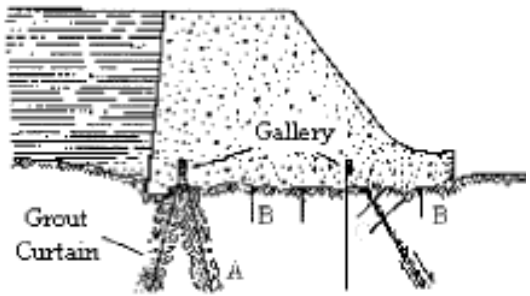
Curtain/Consolidation(blanket) grout

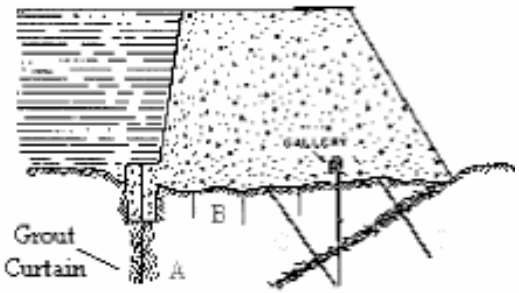


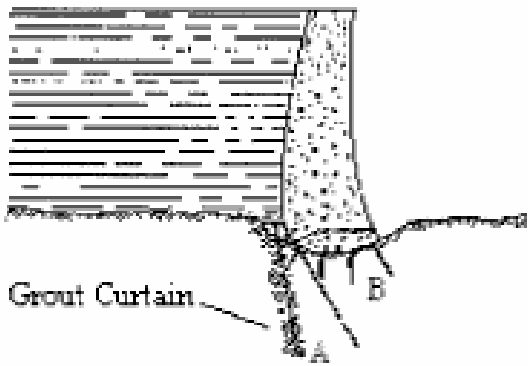


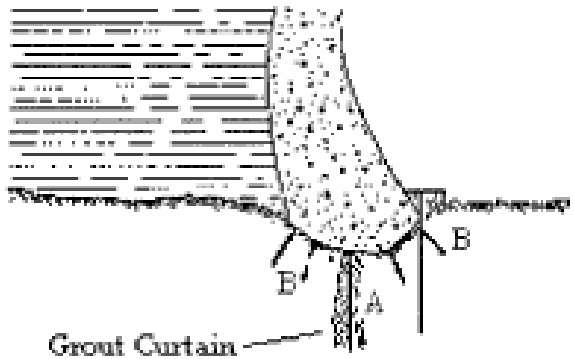






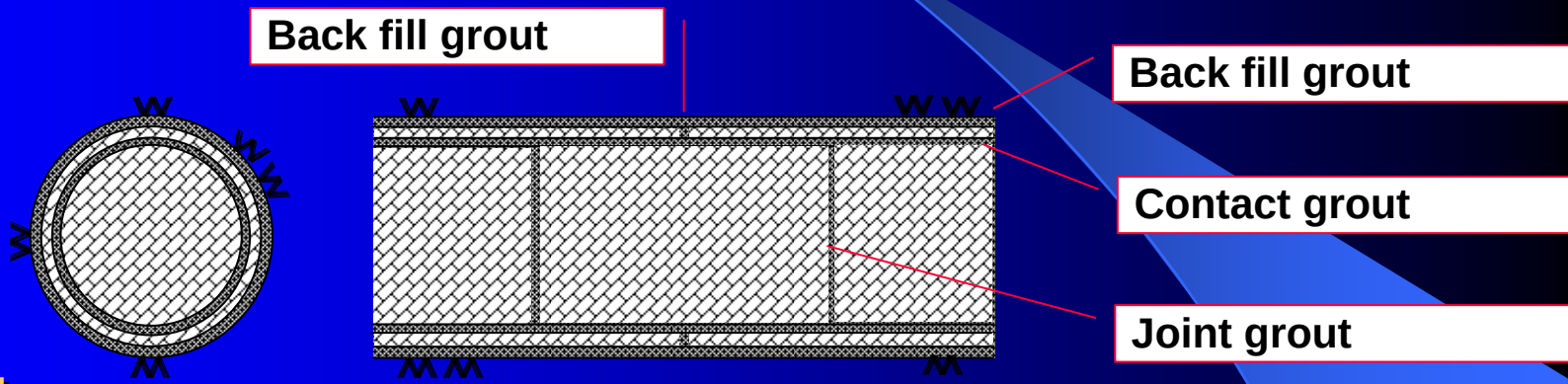






Back fill grout

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

Grout system

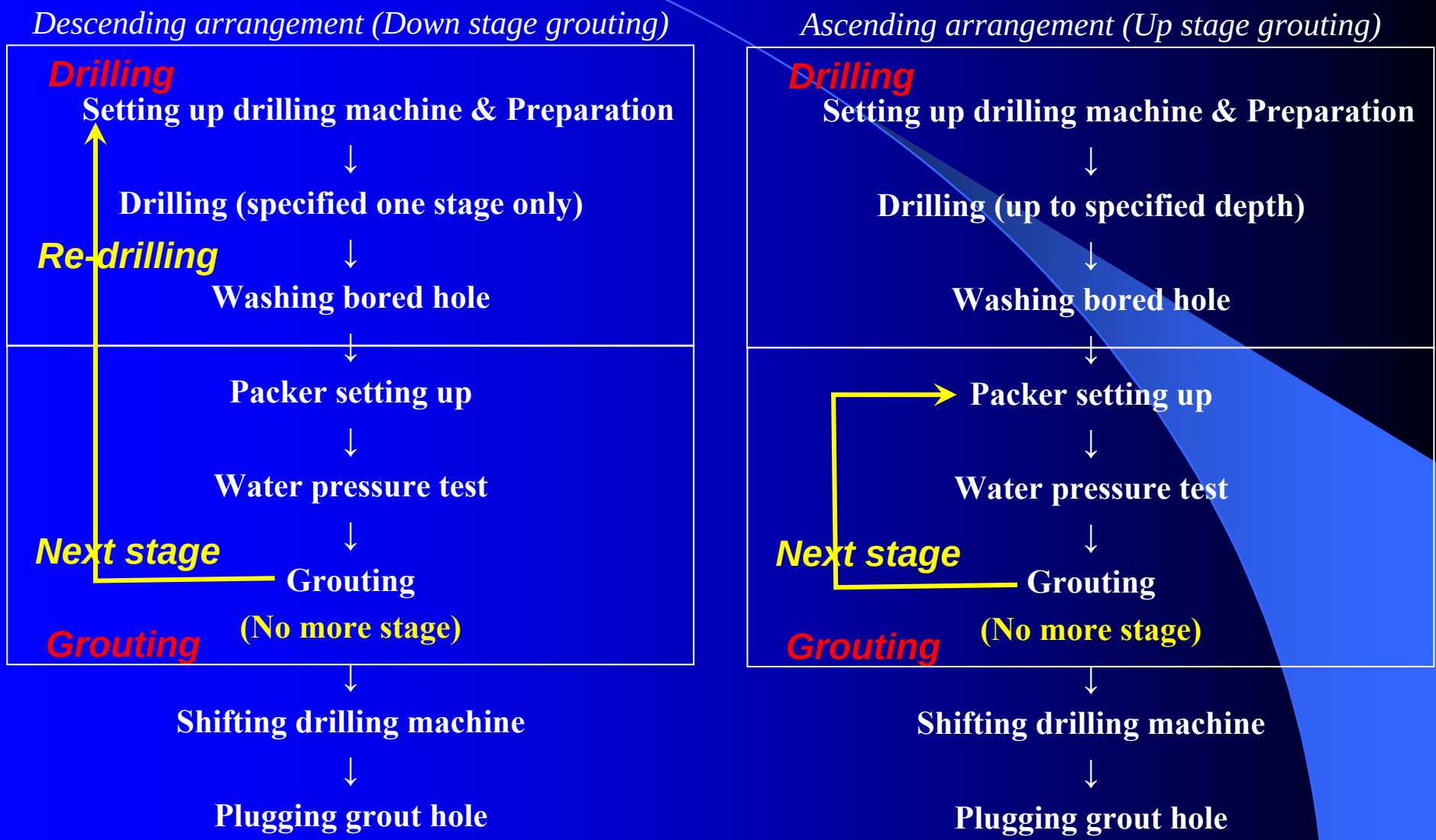
1. Stage grout

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)
Re-drilling
Washing bored hole
Packer setting up
Water pressure test
Next stage
Grouting
(No more stage)
Grouting
Shifting drilling machine
Plugging grout hole
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
Next stage
Grouting
(No more stage)
Grouting
Shifting drilling machine
Plugging grout hole

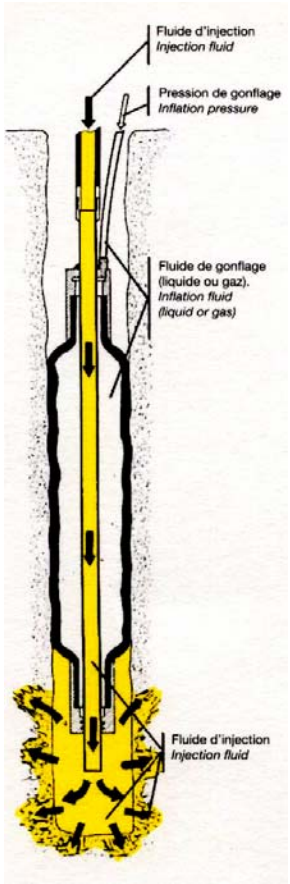
Grout system

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/cm^2 for 10 minutes per meter. The target Lu value after foundation treatment is generally 3 to 5.

Stage	Pressure (bar)	Time duration of each step	
		Pilot/Control hole	Other hole
1st	1→3→1	9 min.	5 min.
2nd	2→5→2	9 min.	5 min.
3rd	2→5→6→5→2	9 min.	5 min.
4th	2→5→7→5→2	9 min.	5 min.

Lu test



Lu-value = 10×Q / (L×P)

Q: Injection volume (L/min.)

L: Test length (m)

P: Test pressure (kg/cm2)

In case h1 ≥ h3 P = P0 + (h2+h3)/10 (kg/cm2)

In case h1 < h3 P = P0 + (h2+h1)/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

P<N

Ratio	Batch	Volum	L/m
4/1	3	651	217
2/1	5	875	292
1/1	6	1200	400
0.7/1	7	1449	483

P<N

Ratio	Batch	Volum	L/m
4/1	2	434	145
2/1	3	525	175
1/1	4	800	267
0.7/1	5	1035	345

LEGEND:

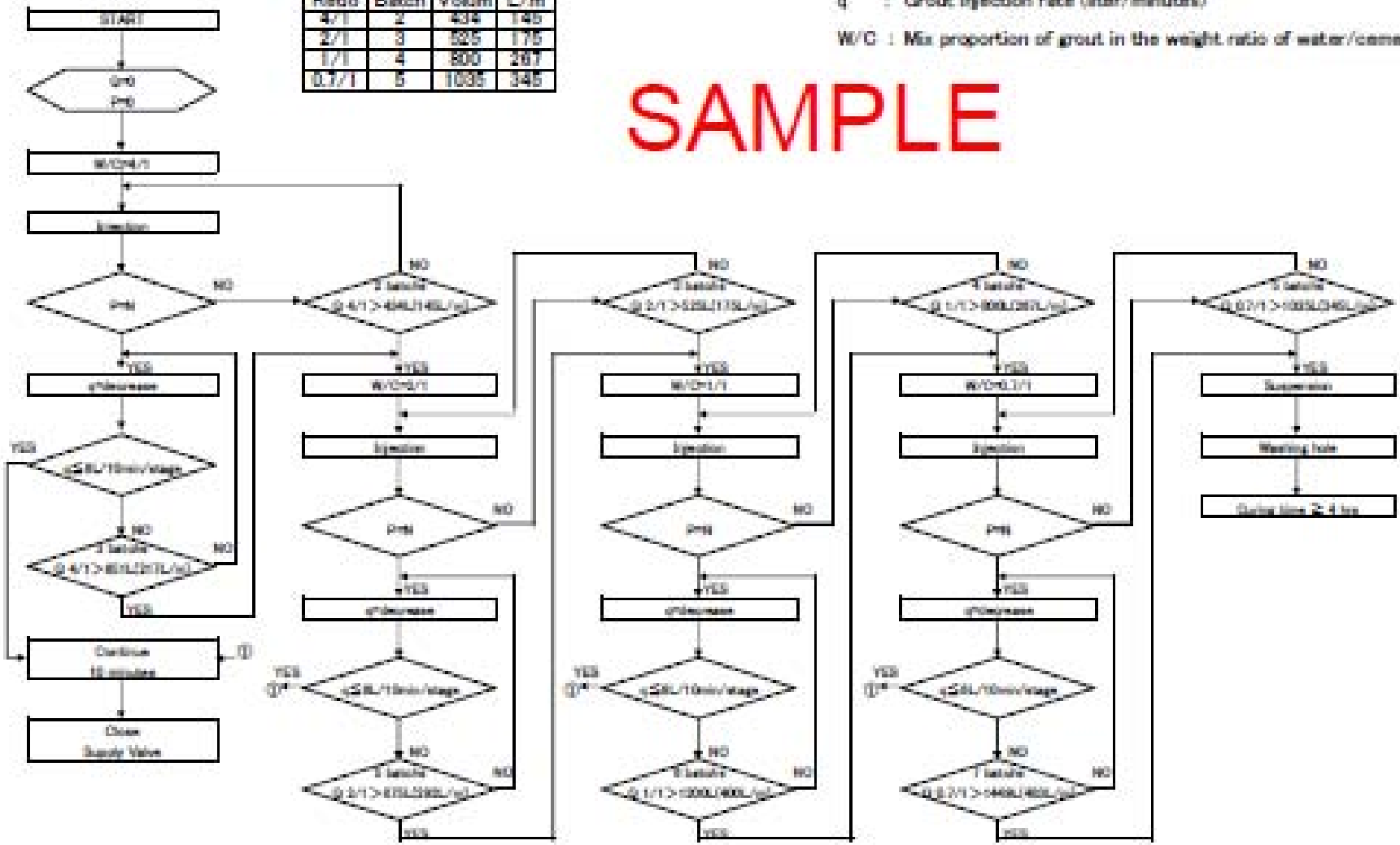
Q 2/1: Total grouting volume of certain mix proportion injected (liter) (The suffix 2/1 indicates the mix proportion W/C)

P : Grouting pressure (kg/cm2)

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

q : Grout injection rate (liter/minutes)

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



Grout system

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 ow 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.

Evaluation of grout result

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

Project name : ------- Dam Project
Grout type : Curtain grout primary line
Block : Block ---

Stage	P1	P2	P3	P4	P5	P6	P7	P8	P9	P10	P11	P12	P13	P14	P15	P16	P17	P18	P19	P20	P21	P22	P23	P24	P25	P26	P27	P28	P29	P30
1	3.0	3.0	3.0	4.5	2.0	3.0	4.1	3.5	2.7	4.1	4.5	3.9	5.2	5.5	5.8	5.2	5.2	5.1	4.7	6.8	5.3	6.6	1.7	1.5	5.2	5.8	1.6	5.4	4.2	4.4
2	5.0	4.0	4.0	5.9	3.0	4.0	3.7	1.7	2.5	3.3	2.1	1.7	5.3	5.6	5.1	6.1	6.0	4.8	3.5	3.4	4.6	4.1	3.6	4.5	3.9	2.4	2.2	6.8	4.6	4.8
3	8.7	7.0	7.0	18.9	7.0	12.9	3.3	1.2	2.5	1.5	4.1	3.8	5.4	5.7	5.9	4.1	3.7	4.5	3.3	4.3	4.8	5.8	4.4	3.7	5.8	5.5	6.7	5.0	2.0	5.0
4	12.7	13.2	15.2	25.0	15.2	13.2	3.5	2.8	4.1	1.7	4.0	6.4	4.6	3.9	4.9	5.7	4.3	4.4	3.7	6.8	4.0	4.2	5.9	5.9	3.8	2.7	6.9	2.5	1.9	2.2
5	10.4	13.7	15.3	20.2	15.3	13.7	13.7	4.1	5.2	5.2	2.7	4.9	4.2	3.1	5.2	5.2	4.2	4.5	3.8	7.3	5.7	4.9	6.7	4.7	6.0	6.7	6.1	4.3	2.3	2.1
6	11.3	12.6	13.7	17.8	13.9	12.6	8.2	4.1	5.2	8.7	5.2	10.4	4.1	3.8	4.1	5.1	4.7	4.6	7.9	7.4	7.4	5.5	5.4	3.2	3.9	3.8	6.9	6.3	4.5	2.2
7	9.6	9.6	9.6	14.8	13.2	9.6	8.2	3.7	8.7	3.7	13.2	12.9	13.8	5.1	6.3	5.9	4.8	9.7	8.1	5.2	6.4	4.2	5.1	5.3	6.5	3.6	6.2	4.9	4.7	2.8
8	8.2	8.2	8.2	12.6	12.1	8.2	8.2	5.2	4.1	5.2	3.7	12.2	13.2	4.9	5.9	4.6	7.2	8.9	8.3	8.3	6.9	6.1	6.2	6.3	6.4	6.3	4.1	4.5	4.1	2.2
9	3.8	3.8	8.2	8.2	8.2	8.2	3.7	4.1	3.7	3.7	13.2	3.7	5.7	4.1	5.7	4.7	4.5	1.3	3.3	2.3	1.7	5.7	2.3	4.0	4.1	6.8	8.5	6.4	5.2	8.7
10	3.2	3.2	7.0	6.9	8.2	8.2	3.3	5.2	5.2	3.7	1.7	2.1	1.8	2.3	2.1	2.3	1.1	1.2	1.7	12.0	18.9	7.0	12.9	2.3	5.4	6.6	8.6	8.4	6.2	7.0
11	5.7	5.7	5.7	5.7	5.7	5.2	5.2	5.2	2.1	1.8	2.3	2.1	2.3	5.7	3.9	4.1	4.3	1.4	5.7	12.0	19.0	15.2	13.2	1.9	5.4	7.6	4.1	6.0	7.9	10.0
12	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2	1.7	3.3	2.3	1.7	5.7	2.3	4.0	4.2	4.4	1.6	16.2	15.3	18.7	15.3	13.7	13.7	7.5	7.4	7.7	8.3	13.7	11.0
13	4.3	4.3	4.3	4.3	4.3	5.2	5.2	5.2	5.7	1.7	7.0	18.9	7.0	12.9	2.3	1.9	1.7	11.0	5.7	13.7	17.8	13.9	12.6	1.9	7.3	5.6	7.8	12.0	18.7	15.0
14	4.1	4.1	4.1	4.1	4.1	9.6	5.9	9.6	9.6	5.7	15.2	25.0	15.2	13.2	1.2	2.3	1.9	1.8	5.7	9.6	14.8	13.2	9.6	5.7	7.2	5.8	14.2	12.0	15.2	16.0
15	3.7	3.7	3.7	3.7	3.7	5.7	12.6	13.7	5.7	16.2	27.0	22.0	15.3	13.7	1.9	1.9	3.4	1.9	2.0	12.0	13.1	13.7	12.8	13.9	7.1	12.5	13.0	10.5	17.0	22.0
16	3.3	3.3	3.3	3.3	3.3	9.6	9.6	9.6	9.6	5.7	13.7	17.8	13.9	12.6	1.9	3.3	1.9	3.5	2.2	2.1	14.8	2.9	3.0	10.0	13.0	12.0	15.8	18.0	24.0	25.0
17	3.5	3.5	3.5	3.5	3.5	9.6	5.7	9.6	9.6	5.7	9.6	14.8	13.2	9.6	5.7	3.6	3.7	3.8	2.3	2.4	4.3	2.8	2.9	2.7	14.2	10.0	11.2	22.8	22.5	26.0
18	2.7	2.7	2.7	2.7	2.7	2.7	5.7	5.7	5.7	2.3	8.2	12.6	12.1	8.2	5.7	3.9	4.0	4.1	2.5	4.2	1.0	2.7	4.4	2.8	8.2	14.7	15.0	18.0	15.0	21.0
19	2.3	2.3	2.3	2.3	2.3	5.7	2.1	1.8	2.3	2.1	5.7	2.3	5.7	5.7	2.3	2.3	4.5	1.9	3.1	3.2	3.0	1.9	3.8	3.2	8.1	14.0	12.0	14.6	17.0	15.0
20	1.7	1.7	1.7	1.7	1.7	2.2	1.9	2.3	2.3	1.9	1.9	2.3	1.9	1.9	1.1	1.4	1.2	0.9	1.9	2.7	1.7	2.1	1.9	2.2	5.4	8.0	14.1	12.7	13.0	14.0

0 ≦ Lu > 3	10 ≦ Lu > 15
3 ≦ Lu > 5	15 ≦ Lu > 20
5 ≦ Lu > 7	20 ≦ Lu
7 ≦ Lu > 10	

Cement intake Map

Project name : ------- Dam Project
Grout type : Curtain grout primary line
Block : Block ---

Stage	P1	P2	P3	P4	P5	P6	P7	P8	P9	P10	P11	P12	P13	P14	P15	P16	P17	P18	P19	P20	P21	P22	P23	P24	P25	P26	P27	P28	P29	P30
1	4.1	4.1	4.1	5.6	3.1	4.1	5.2	4.6	3.8	5.2	5.6	5.0	6.3	6.6	6.9	6.3	6.3	6.2	5.8	7.9	6.4	7.7	2.8	2.6	6.3	6.9	2.7	6.5	5.3	5.5
2	6.1	5.1	5.1	7.0	4.1	5.1	4.8	2.8	3.6	4.4	3.2	2.8	6.4	6.7	6.2	7.2	7.1	5.9	4.6	4.5	5.7	5.2	4.7	5.6	5.0	3.5	3.3	7.9	5.7	5.9
3	9.8	8.1	8.1	15.0	8.1	14.0	4.4	2.3	3.6	2.6	5.2	4.9	6.5	6.8	7.0	5.2	4.8	5.6	4.4	5.4	5.9	6.9	5.5	4.8	6.9	6.6	7.8	6.1	3.1	6.1
4	13.8	14.3	16.3	12.0	16.3	14.3	4.6	3.9	5.2	2.8	5.1	7.5	5.7	5.0	6.0	6.8	5.4	5.5	4.8	7.9	5.1	5.3	7.0	7.0	4.9	3.8	8.0	3.6	3.0	3.3
5	11.5	14.8	16.4	10.0	16.4	14.8	14.8	5.2	6.3	6.3	3.8	6.0	5.3	4.2	6.3	6.3	5.3	5.6	4.9	8.4	6.8	6.0	7.8	5.8	7.1	7.8	7.2	5.4	3.4	3.2
6	12.4	13.7	14.8	18.9	15.0	13.7	9.3	5.2	6.3	9.8	6.3	11.5	5.2	4.9	5.2	6.2	5.8	5.7	9.0	8.5	8.5	6.6	6.5	4.3	5.0	4.9	8.0	7.4	5.6	3.3
7	10.7	10.7	10.7	15.9	14.3	10.7	9.3	4.8	9.8	4.8	14.3	14.0	14.9	6.2	7.4	7.0	5.9	10.8	9.2	6.3	7.5	5.3	6.2	6.4	7.6	4.7	7.3	6.0	5.8	3.9
8	9.3	9.3	9.3	13.7	13.2	9.3	9.3	6.3	5.2	6.3	4.8	13.3	14.3	6.0	7.0	5.7	8.3	10.0	9.4	9.4	8.0	7.2	7.3	7.4	7.5	7.4	5.2	5.6	5.2	3.3
9	4.9	4.9	9.3	9.3	9.3	9.3	4.8	5.2	4.8	4.8	14.3	4.8	6.8	5.2	6.8	5.8	5.6	2.4	4.4	3.4	2.8	6.8	3.4	5.1	5.2	7.9	9.6	7.5	6.3	9.8
10	4.3	4.3	8.1	8.0	9.3	9.3	4.4	6.3	6.3	4.8	2.8	3.2	2.9	3.4	3.2	3.4	2.2	2.3	2.8	13.1	20.0	8.1	14.0	3.4	6.5	7.7	9.7	9.5	7.3	8.1
11	6.8	6.8	6.8	6.8	6.8	6.3	6.3	6.3	3.2	2.9	3.4	3.2	3.4	6.8	5.0	5.2	5.4	2.5	6.8	13.1	20.1	16.3	14.3	3.0	6.5	8.7	5.2	7.1	9.0	11.1
12	6.3	6.3	6.3	6.3	6.3	6.3	6.3	6.3	2.8	4.4	3.4	2.8	6.8	3.4	5.1	5.3	5.5	2.7	17.3	15.4	19.8	16.4	14.8	14.8	8.6	8.5	8.8	9.4	14.8	12.1
13	5.4	5.4	5.4	5.4	5.4	6.3	6.3	6.3	6.8	2.8	8.1	20.0	8.1	14.0	3.4	3.0	2.8	12.1	6.8	14.8	18.9	15.0	13.7	3.0	8.4	6.7	8.9	13.1	19.8	16.1
14	5.2	5.2	5.2	5.2	5.2	10.7	7.0	10.7	10.7	6.8	16.3	26.1	16.3	14.3	2.3	3.4	3.0	2.9	6.8	10.7	15.9	14.3	10.7	6.8	8.3	6.9	15.3	13.1	16.3	17.1
15	4.8	4.8	4.8	4.8	4.8	6.8	13.7	14.8	6.8	17.3	28.1	23.1	16.4	14.8	3.0	3.0	4.5	3.0	3.1	13.1	14.2	14.8	13.9	15.0	8.2	13.6	14.1	11.6	18.1	23.1
16	4.4	4.4	4.4	4.4	4.4	10.7	10.7	10.7	10.7	6.8	14.8	18.9	15.0	13.7	3.0	4.4	3.0	4.6	3.3	3.2	15.9	4.0	4.1	11.1	14.1	13.1	16.9	19.1	25.1	26.1
17	4.6	4.6	4.6	4.6	4.6	10.7	6.8	10.7	10.7	6.8	10.7	15.9	14.3	10.7	6.8	4.7	4.8	4.9	3.4	3.5	5.4	3.9	4.0	3.8	15.3	11.1	12.3	23.9	23.6	27.1
18	3.8	3.8	3.8	3.8	3.8	3.8	6.8	6.8	6.8	3.4	9.3	13.7	13.2	9.3	6.8	5.0	5.1	5.2	3.6	5.3	2.1	3.8	5.5	3.9	9.3	15.8	16.1	19.1	16.1	22.1
19	3.4	3.4	3.4	3.4	3.4	6.8	3.2	2.9	3.4	3.2	6.8	3.4	6.8	6.8	3.4	3.4	5.6	3.0	4.2	4.3	4.1	3.0	4.9	4.3	9.2	15.1	13.1	15.7	18.1	17.1
20	2.8	2.8	2.8	2.8	2.8	3.3	3.0	3.4	3.4	3.0	3.0	3.4	3.0	3.0	2.2	2.5	2.3	2.0	3.0	3.8	2.8	3.2	3.0	3.3	6.5	9.1	15.2	13.8	14.1	15.1

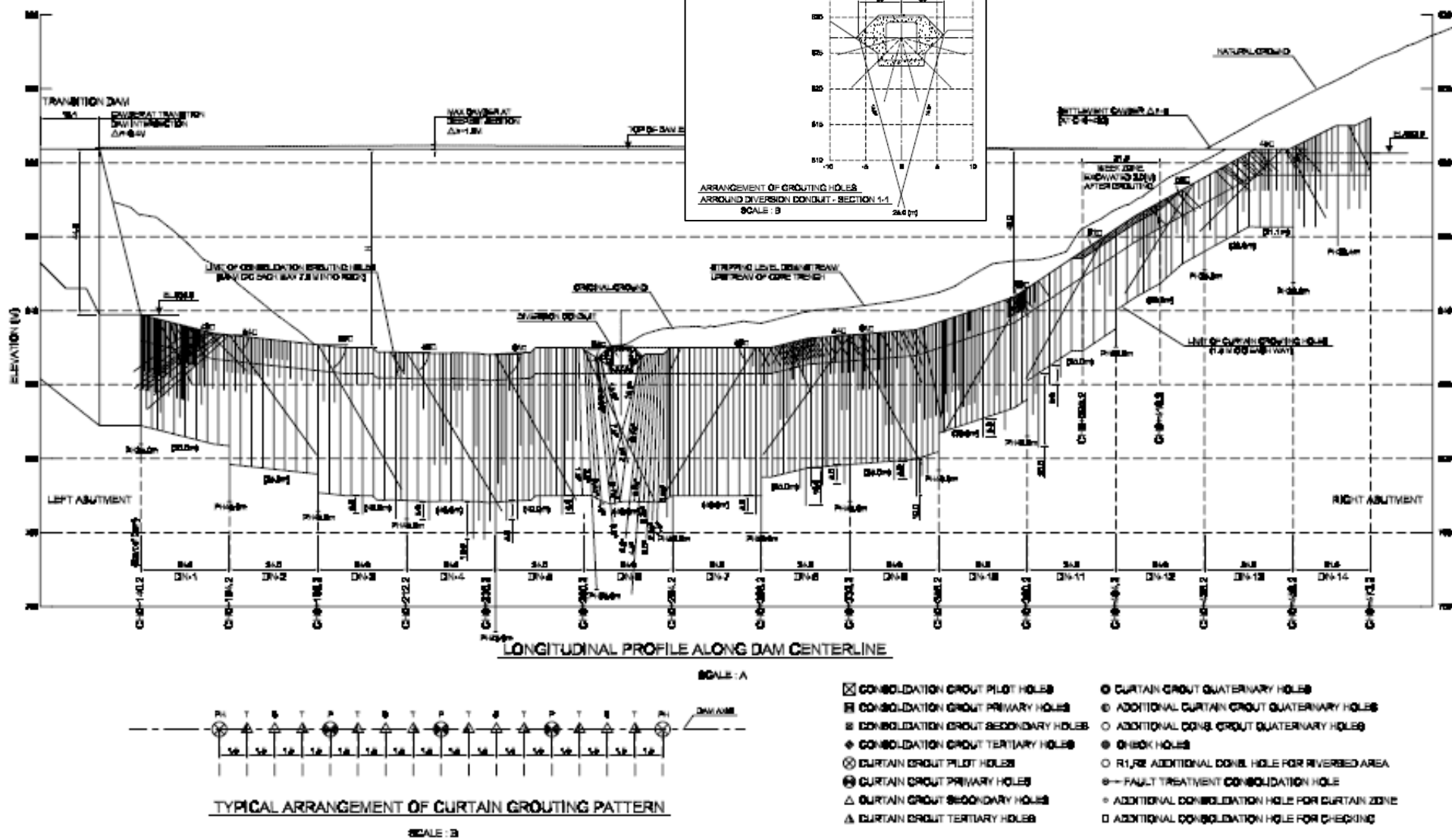
0 ≦ kg/m > 3	10 ≦ kg/m > 15
3 ≦ kg/m > 5	15 ≦ kg/m > 20
5 ≦ kg/m > 7	20 ≦ kg/m
7 ≦ kg/m > 10	

Grouting works in Dai Ninh Hydropower dam project

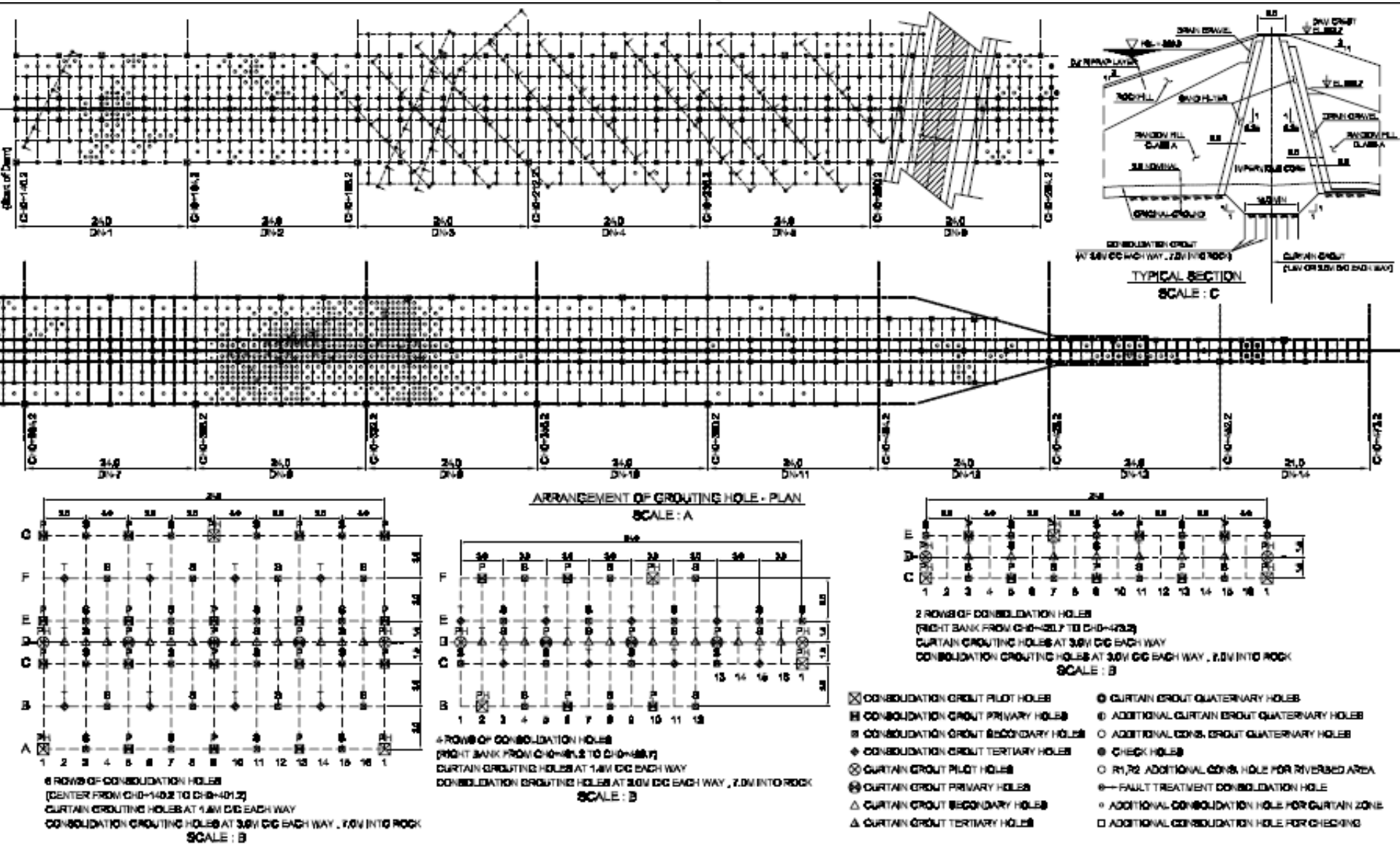
Design quantity

1. Consolidation grout :	41,750m, 7,407stages
2. Curtain grout :	37,440m, 6,643satges
3. Consolidation core drilling : pilot and check hole	4,650m
4. Curtain core drilling : pilot and check hole	4,250m
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 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-
地球に
KOKEN
する会社。

LSI card-------Data base-------Analysis--------Reporting

Cement silo

Grout control compound

Supply control system

Mixing control system

Bentnite Supply

Admixture Supply

Automatic grout recording system

通信ケーブル

Supply

Automatic mixing plant

Water supply

Return

Return

Sub plant

Water treatment plant

Automatic grout system

Dam grout system flow chart

Grout hole

Grout hole

Grout hole

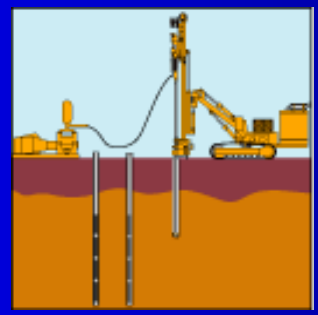
明昭株式会社

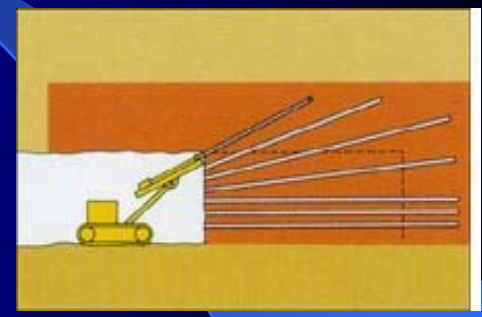
KOKEN PRODUCT

– for Dam Construction-

Anchoring

Drain hole drilling





Shaft drilling

Grouting