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DESIGN OF FOUNDATION TREATMENT (CURTAIN GROUTING) AT OYAMA DAM

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1 INTRODUCTION

The geology of Oyama Dam consists mainly of Shakadake volcanic rocks - andesitic lava spewed from the volcano which was active about 3.1 to 4.1 million years ago. Because this geology originates from lava and is relatively new in geological age, it has not been subjected to a vertical load continuously to date and it is not always true that the bed rock becomes harder toward deep part. Thus, the curtain grouting of Oyama Dam was designed extremely deeper than typical dams, about twice the depth of dam height at the maximum, in consideration of the hydro-geological structure. The method of early construction of the curtain grouting in deep part was adopted in Oyama Dam, as the construction of the curtain grouting in deep part after casting of concrete of the main body greatly influences the process to the first impoundment.

As a result of early construction of curtain grouting in the right bank slope from June 2008, it was proved that improvement to an original target level would be difficult in CL-class bed rock in the superficial part. A test construction was performed in consideration of this situation, and the characteristics of grouting in the superficial part of the right bank were investigated. Originally planned single-row curtain grouting was changed to three-row one at a lower target improvement level.

The plan and construction of grouting of the dam is based on “the grouting technical guide (in 2003)” in principle. However, this guide only describes the construction of more than single-row grouting: “If the creep length is short or the improvement is difficult, a thick impervious zone by constructing three-row grouting, etc. is recommended”. This suggests specific plans and constructions are needed to be decided depending on the situation.

This report mainly describes the process of changing plan to three-row curtain grouting in the right bank slope and its concept.

2 THE OUTLINE OF GEOLOGY, OYAMA DAM

2.1 TOPOGRAPHICAL AND GEOLOGICAL FEATURES ON A REGIONAL SCALE

The Akaishi River basin at the east end of Oita Prefecture, in which Oyama Dam is located, is a mountainous area with height of 300 to 1200 meters (Tsue mountains), covering the east side of Chikuhi mountains near the border of Fukuoka and Kumamoto Prefectures. Geological feature of Tsue mountains is mainly volcanic products (such as volcanic rocks and pyroclastic rocks) from volcanic activity from Neogene of Caenozoic era, Pliocene, to Pleistocene of Quaternary Period, and that forms precipitous mountains, 500 to 1100 meters in height, and pyroclastic plateau which forms flat surface at the height of 400 to 600 meters. The hillside slope where reservoir is located is precipitous with about 30° to 45° of gradient, and the steep escarpments are often formed by andesite and Yabakei pyroclastic flow deposit (ignimbrite).

The Akaishi River originates from Togamidake (1150 meters in height) at about eight kilometers south of the dam site, and flows toward the north and north-northeast with forming a precipitous river valley. Tributaries such as the Ono River (Umegi River), the Takenosako River, and the Gogoro River flow into the Akaishi River to meet the Chikugo River (Oyama River) at about two kilometers lower reaches of the dam site, (Nakagoura, Oyama-machi). The catchment area of the dam is 33.6 km2.

2.2 TOPOGRAPHICAL AND GEOLOGICAL FEATURES OF THE DAM SITE

The dam site is located on the Akaishi River, about 2km upstream from the junction of the Akaishi River and the Oyama River. The altitude of the riverbed around the dam site is about 174 m, and the bed slope is about 1/30 to 1/33. The slope gradient is precipitous, about 30° to 40°.

The bedrock of the dam site consists of principally andesite and autobrecciated andesite of Shakadake volcanic rocks, and Yabakei pyroclastic flow deposit spreads over it in the high elevation area (far above the surcharge water level). Furthermore, halfway up the slope is interspersed with Aso pyroclastic flow deposit, covering Shakadake volcanic rocks directly.

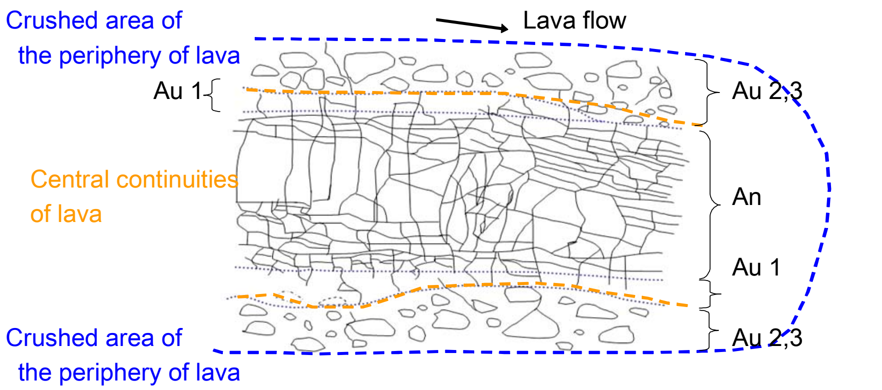
The structural feature of Shakadake volcanic rocks, which are the foundation rock of the dam, is that andesite and autobrecciated andesite overlap in alternate layers at right bank downstream slope. It seems that the origin of this structure is andesitic block lava flowed repeatedly (See Fig. 1, Photograph 1). It can be assumed that andesite is central continuities of lava while autobrecciated andesite is a crushed area around lava at the time of lava flow.

Andesite is classified into An Ⅰ to Ⅶ, and Kan Ⅰ to Ⅵ in the order of lowest unit to highest of left bank deep part. Andesite is basically distributed from left bank upstream to right bank downstream slopes, but only in An VI layer around the riverbed of right bank, it is virtually found in the upstream and downstream direction. Autobrecciated andesite has a variety of lithofacies depending on the position within lava unit, the form of lava eruption and the condition at the time of flow to be divided into three major types (Autobrecciated andesite type 1, type 2 and type 3).

In view of engineering property of bed rock and water permeability, andesite and autobrecciated andesite, which are the foundation rock, are divided into andesite group and massive andesite group by hardness and the degree of development of fissures (Table 1). Autobrecciated andesite type 1 is categorized as autobrecciated andesite from petrogenetic point of view, but it is classified into andesite group due to its distribution and engineering/permeability properties similar to those of andesite.

It is assumed that unlike lava, lapilli tuff and tuff breccias are sedimentary rocks composed of mixture of blocks of volcanic rocks and tuffaceous matrix. Lapilli tuff is distributed in the deep part of left bank, and tuff breccia is distributed in the middle part of the right bank with layer thickness of 10-15 meters, often with that of several meters within lava unit.

While the geology in superficial part of the right bank slope in which three-row curtain grouting is constructed shows thickly deposited CL-class autobrecciated andesite of type 3, other layer of autobrecciated andesite is mainly classified as CM-class, indicating their different features (Fig. 2).



An : Andesite
Au1,2,3: Autobrecciated Andesite type 1,2,3

Fig. 1
Schematic diagram of lava (Andesite)

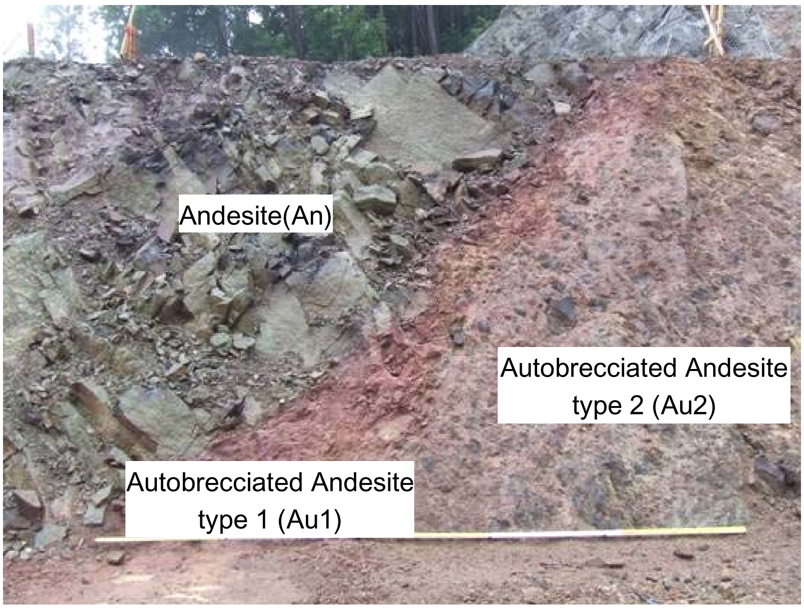


Table 1
Classification of bed rock

Group of rocks	geologic classification	Features
Andesite (An) group	Andesite (An)	Central continuities of lava
	Autobrecciated Andesite type 1(Au 1)	Crushed area of the periphery of lava Composed of andesite block and matrix with unclear boundary
Autobrecciated Andesite	Autobrecciated Andesite type 2 (Au 2)	Crushed area of the periphery of lava Composed of andesite block and matrix

(Au) group	Autobrecciated Andesite type 3 (Au 3)	Crushed area of the periphery of lava Composed of andesite block and matrix

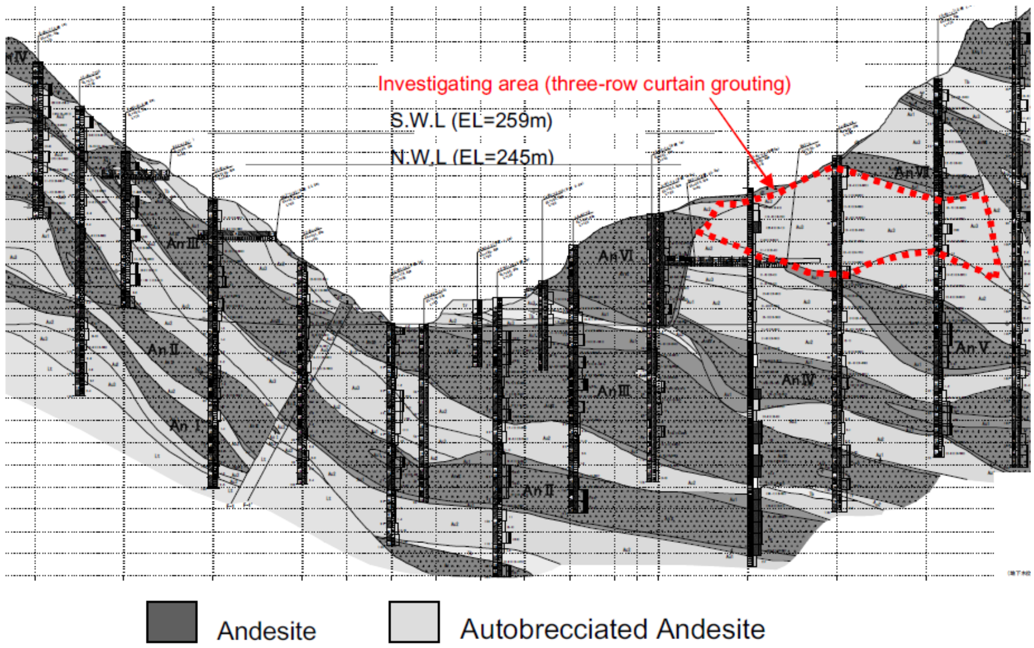


Fig.2
Geological cross section at dam axis

3. CONCEPT OF INITIAL PLAN FOR THE GROUTING,

3.1 OYAMA DAM

3.1.1 Basic concept of hydro-geological structure of the dam site

The water permeability of the dam foundation rock was divided into the following two groups according to the geology of dam site, and the foundation treatment was planned with a focus on andesite (An) group with an assumed fracture system model as shown in Fig.3.

- A group of andesite (An) having a lot of fissures and high water permeability (andesite [An], autobrecciated andesite type 1 [Au1])

- A group of autobrecciated andesite (Au) having a few fissures and low water permeability (autobrecciated andesite type 2 [Au2], autobrecciated andesite type 3 [Au3])

As for the continuity of water path, it seems that andesite layer continuing in the upstream and downstream directions may result in water path as andesite group has a lot of fissures, while autobrecciated andesite group has a few fissures and is less likely to lead to water path particularly at a depth of 50 meters or more which is less affected by weathering.

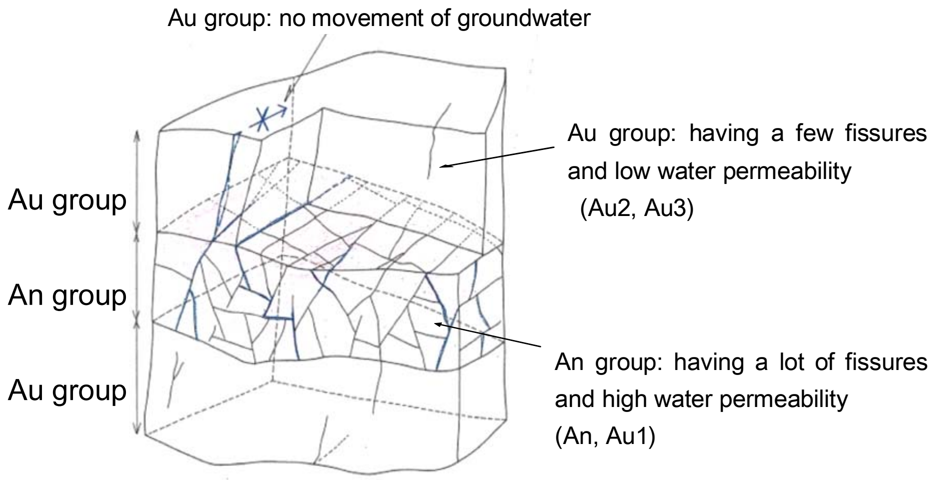


Fig.3
Schematic diagram of fissures of foundation rocks

3.2 BASIC CONCEPT OF CURTAIN GROUTING

The improvement target level: about 2 Lu for the area from 0 to H/4 (H: maximum height of dam) in depth, 5 Lu for the area from H/4 to H/2 in depth, and 10 Lu for the depth of H/2 or more.

The improvement area in the direction of depth is, for the dam body, the range outside the improvement target level, less than surcharge water level within the area equivalent to dam height. However, for the area that is higher than the dam height, the area outside the improvement target level in the continuous layer of andesite in the dam downstream surface will be included in consideration of hydro-geological structure.

Fig. 4 shows the area of curtain grouting construction, which was originally planned.

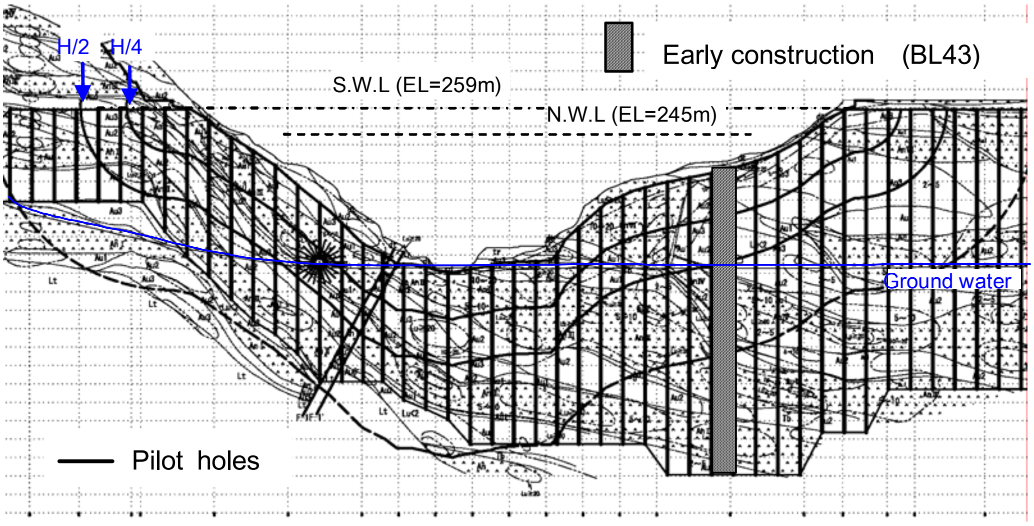


Fig.4
Initial plan of the curtain grouting

4. THE RESULT OF EARLY CONSTRUCTION OF CURTAIN GROUTING

4.1. EARLY CONSTRUCTION

The depth of curtain grouting is usually equivalent to the dam height according to “the grouting technical guide”, but the construction of grouting in Oyama Dam is planned to be installed up to the depth of about twice the dam height (180 meters) in view of hydro-geological structure.

For this reason, the rule is to construct curtain grouting after the dam body is built up to a designated height (15 meters), but it was decided to construct the deep body with more than H 25 meters (deeper than H/4) before concrete placement to reduce the influences on process prior to the first impoundment.

As a result, the improvement to the target value was assumed to be difficult especially in the superficial part of right bank. The results are shown below.

4.2 CONSTRUCTION RESULTS OF SINGLE-ROW CURTAIN

Construction was implemented to tertiary holes (1.5 meters of holes spacings), single-row curtain of one higher order than design holes, in BL 43 of right bank slope to confirm the specifications of construction and improvement effect of curtain grouting.

As a result, in autobrecciated andesite type 3 (Au 3) in the superficial part of right bank, difficulties in achievement of target level were expected in 2 Lu and 5 Lu at 1.5 meters holes spacings, showing the necessity of many additional holes.

Fig. 5 demonstrates the Lugeon map; Table 2, Lugeon values of exceedance probability from the construction result. Table 2 is organized only by the result of autobrecciated andesite type 3 (Au 3) (depth of 0-45 meters), which accounts for most part of the target area in geology.

In the tertiary holes (1.5 meters spacings), the value of exceedance probability of 15% is 13.3 Lu when the improvement target is 2Lu; 12.2 Lu when the improvement target is 5 Lu. The rate of exceeding the improvement target level is 84% and 44%, respectively. The result suggests that quite a few additional holes with less than 75 cm of spacings be needed to meet the originally designed improvement target level.

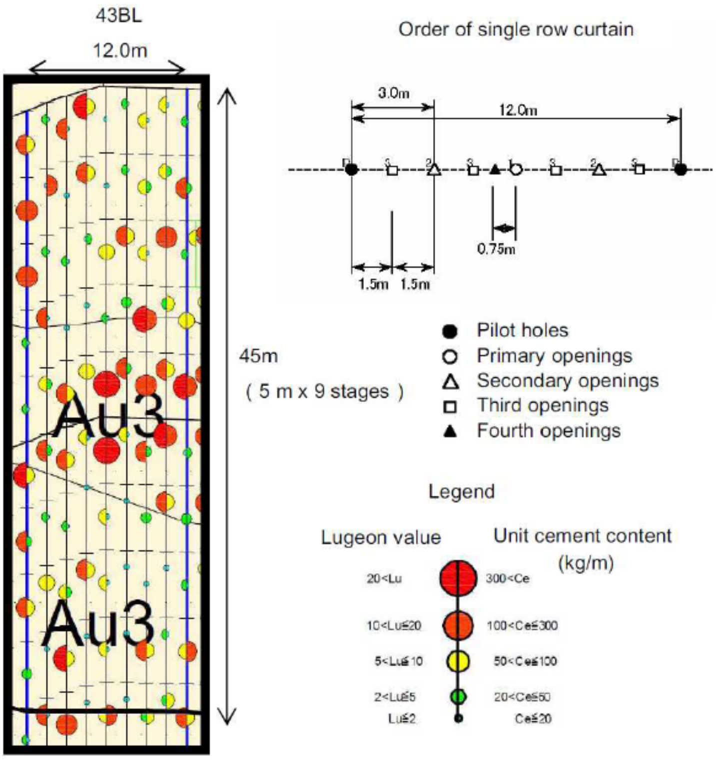


Fig. 5
Construction result of single row curtain in BL 43 of superficial part

Table 2
Result of curtain grouting at BL 43 (0-45 m depth)

At the area of improvement target level of 2Lu

Order of openings	Number of stages	Target level excess probability	Lugeon value of 15% excess probability	Average of lugeon value
P	5	100%	-	8.4
1	5	57%	-	7.1
2	10	80%	18	9.4
3	20	84%	13	7.5

At the area of improvement target level of 5Lu

Order of openings	Number of stages	Target level excess probability	Lugeon value of 15% excess probability	Average of lugeon value
P	4	77%	-	42
1	4	64%	-	6.2
2	8	61%	31	11
3	16	44%	12	5.9

5. IMPLEMENTATION OF TEST CONSTRUCTION

5.1 THE GEOLOGY OF THE SUPERFICIAL PART OF RIGHT BANK

Fig. 6 illustrates the geological section of the superficial part of right bank. The geology of the superficial part of right bank which is difficult to improve differs depending on the depth, deeper than 40-50 meters and shallower than that. The former geology mainly consists of alternate layer of andesite group and autobrecciated andesite group. In the latter geology, a thick andesite group is distributed (An VI layer) on the river bed side; autobrecciated andesite type 3 (Au 3) of a thick soft autobrecciated andesite group (equivalent to CL-class), on the right bank side.

It is considered as follows. There was a change in the volcanic activity by lava deposition, where high temperature lava had stopped flowing to flow low temperature Au 3 only. Subsequently, the river bed side was eroded widely as this Au 3 has a tendency of low concreteness for easy erosion. Thus, it would appear that the thick andesite group is now distributed on the river bed side of BL 41 after the high temperature lava flow (An VI layer) filled in the eroded depression of Au 3 at time of lava activity resumption.

There is a possibility that the assessment of grouting varies widely between each area because of differences in characteristics of geological distribution and those described below. Therefore, the geology of the part is divided into two areas: R-1 and R-2.

R-1：Mainly alternate layer of An group and Au group
R-2：Thick Au group (Au 3)

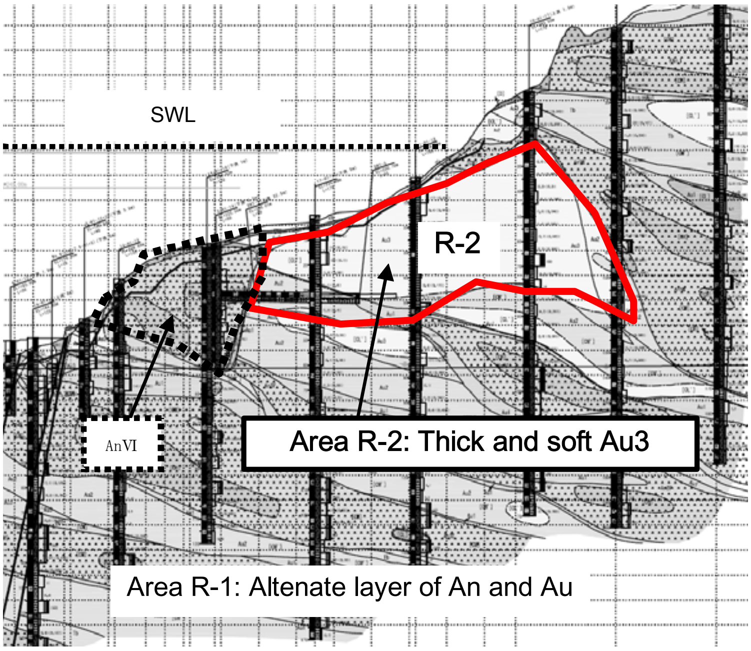


Fig. 6
Geological section at right bank

5.2 THE PURPOSE OF TEST CONSTRUCTION

In the current foundation treatment plan, curtain grouting is single-row. However, as a result of early construction of curtain grouting, it is assumed that the improvement target level of 2 Lu for the superficial part will not be achieved when the opening spacings are 75 centimeters.

Also, it is considered that there are some needs to construct a thick impervious zone and to extend creep length (to reduce the hydraulic grade) for ensuring the needed imperviousness because in Au 3, it is impossible to increase the injection pressure due to low critical pressure, and the ridge on the right bank side is precipitous.

For all of these reasons, test construction was conducted to decide the detailed specifications of three-row grouting on the basis of these issues of dam site right bank.

5.3 TEST CONSTRUCTION SCHEME

5.3.1 The Placement of Holes

For layout of holes, 10 meters lattice configuration shown in Fig. 7 was adopted by using the hole arrangement of consolidation grouting designed with the purpose of improving the imperviousness. Opening spacings are shown in Table 3.

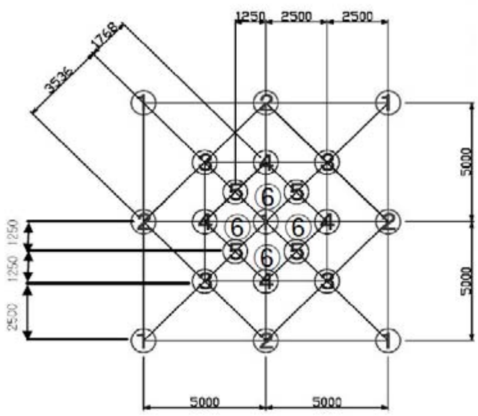


Table 3
Opening spacings

Order	1	2	3	4	5	6
Opening spacings (m)	7.07	5	3.54	2.5	1.77	1.25

5.3.2 A depth and improvement target level

The improved depth of consolidation grouting designed with the purpose of improving the imperviousness is 10 meters (2 stage). The depth of test construction is 40 m (8 stage) to include soft autobrecciated andesite type 3, in consideration of topographical features such as the position of river bed of the Takenosako River in the upstream area.

5.3.3 Test Methods

The fluorescent coating was added to cement fluid, collected core was illuminated with ultraviolet light (black light) to confirm the filling condition of cement fluid by core observation.

Also, cement fluid at a ratio of 1:10 was injected first because it was assumed that the change in grout mix proportion would be difficult to improve.

5.4 THE RESULT OF TEST CONSTRUCTION

5.4.1 Lugeon value

Early permeability (primary holes) was 57 Lu (exceedance probability is 15%: same as followings) as a whole. The permeability was reduced to 7.7 Lu at the stage of secondary holes; about 10 Lu from tertiary holes; about 5 Lu at fifth openings (opening spacings: 1.77 meters) (See Fig.8).

When it was compared between 0-H/4 (1-5 stage) area and H/4-H/2 area (6-8 stage) (See Table 4), both areas were interpolated from 10 meters lattice up to fifth holes (opening spacings: 1.77 meters) in succession and Lugeon value was reduced to about 5 Lu at exceedance probability of 15% value.

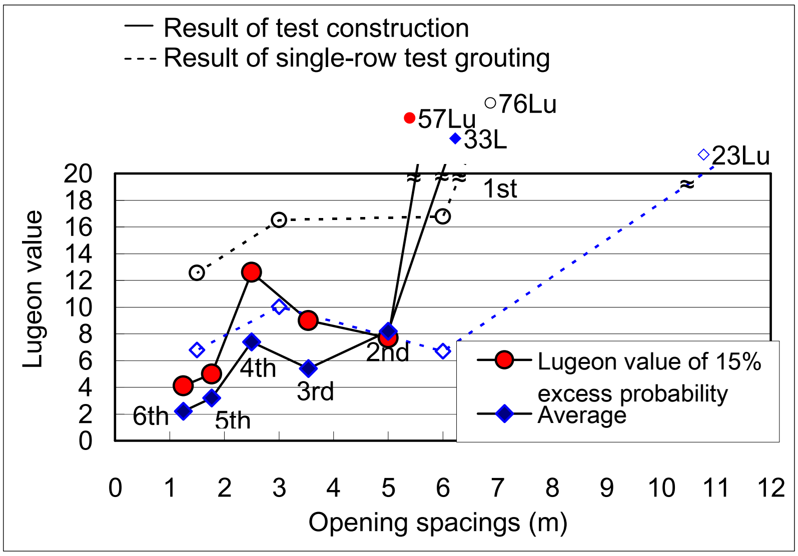


Fig. 8
Relation between opening orders and Lugeon value

Table 5 The result of test construction

At the area of improvement target level of 2Lu

Order of openings	Number of stages	Target level excess probability	Lugeon value of 15% excess probability	Average of lugeon value
1	25	91%	74	45
2	20	70%	9.7	10
3	20	83%	11	6
4	20	65%	8.6	4.5
5	20	39%	4.4	2.8
6	20	34%	2.6	1.8

At the area of improvement target level of 5Lu

Order of openings	Number of stages	Target level excess probability	Lugeon value of 15% excess probability	Average of lugeon value
1	25	33%	13	13
2	20	30%	7.8	4.4
3	20	35%	6.0	4.4
4	20	30%	29	12
5	20	24%	5.5	3.9
6	20	0%	4.6	2.8

High permeability over 20 Lu was hardly observed after secondary holes. About 80% were below 10 Lu after secondary holes, but the ratio of below 2 Lu increased slightly from fourth holes.

The result of single-row test construction showed that construction at 1.5 meters spacings was at 10 Lu or more, but it was improved to about 5 Lu by constructing in a reticular pattern.

5.4.2 Unit Cement Content

As shown in Fig. 9, unit cement content was 75.5 kg/m at primary holes（average value: same as followings）and reduced to 28.2 kg/m at secondary holes. It increased slightly at tertiary holes to reduce gradually after that, resulting in 22.7 kg/m at fourth holes and 12.8 kg/m at fifth holes.

When 0-H/4 area (1-5 stage) was compared to H/4-H/2 area (6-8 stage), unit cement content was stable after secondary holes, although high injection stages were seen after fourth holes for 0-H/4 area (1-5 stage); at fourth holes for 0-H/4 area (1-5 stage).

About 50% of primary holes and 70% after secondary holes were injection at below 20 kg/m.

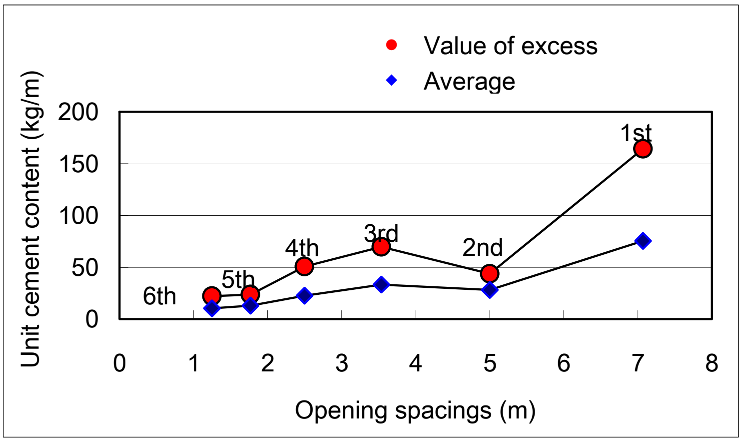


Fig. 9
Relation between opening orders and unit cement content

5.4.3 Occurrence of critical pressure

Table 5 shows occurrence of critical pressure. Divided into the superficial part above 25 m (1-5st) and deeper part (6-8st) than 25 m, the frequency of critical pressure at each order and the distribution of the value are shown. Overall, there is an extreme high frequency of critical pressure and critical pressure itself is very low.

Compared the deep part to superficial one, critical pressure is more likely to be slightly higher in the deep part than in the superficial part, but the incidence of critical pressure is likely to be higher in the deep part than the in the superficial part. This is believed that the deeper, the higher the pressure becomes.

Table 5
Generation status of critical pressure (Pc)

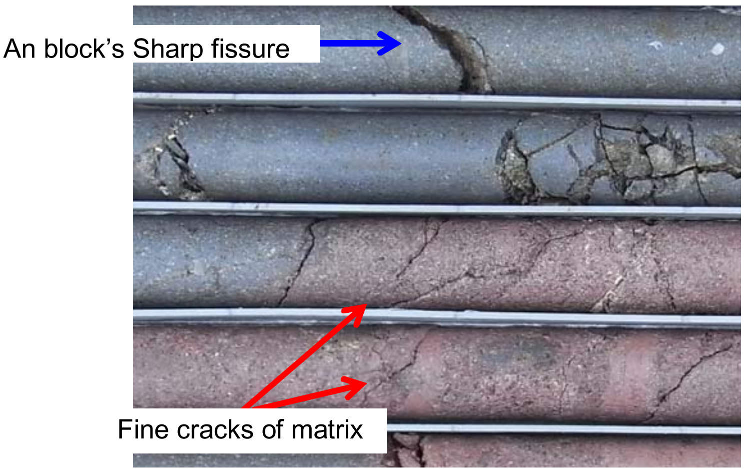
improvement target level	Order of openings	incidence of critical pressure	Pc≦0.2	0.2＜Pc≦0.4	0.4＜Pc≦0.6	0.6＜Pc	None
2Lu	1	60%	52%	4%	4%	0%	40%
	2	75%	50%	25%	0%	0%	25%
	3	70%	25%	45%	0%	0%	30%
	4	65%	45%	20%	0%	0%	35%
	5	55%	10%	30%	10%	5%	45%
	6	10%	5%	5%	0%	0%	90%
5Lu	1	87%	20%	40%	27%	0%	13%
	2	83%	0%	50%	33%	0%	17%
	3	100%	8%	58%	33%	0%	0%
	4	75%	25%	42%	8%	0%	25%
	5	100%	8%	25%	58%	8%	0%
	6	75%	0%	33%	33%	8%	25%

6. CHARACTERISTICS OF GROUTING IN THE RIGHT BANK SLOPE

6.1 GEOLOGICAL CHARACTERISTICS

In the target part, autobrecciated andesite consisting of matrix part and andesite block is distributed. Matrix part is generally void and soft enough to be broken with a hammer pick. There are a lot of hard andesite blocks, but in many cases, the boundary between andesite block and matrix part can be separated.

Andesite block has a lot of fissures in it and is often relatively sharp. Fissures in matrix part are uneven with fine cracks. Many of them lack continuity, but some of them have continuous high-angle fissures (See Photograph 2).



Photograph 2
Fissures and cracks of boring core

At first, autobrecciated andesite was considered to have a small number of continuous fissures and not to have distinct directionality, but from geological conditions after the foundation excavation, it became obvious that there were significantly high-angle continuous fissures in the downstream left bank slope, autobrecciated andesite type 3 (R-2) in right bank slope (Fig. 10). Seemingly, high permeability before constructing the grouting is caused by these fissures.

From this, we assumed geology of R-2 as a model like Fig. 11.

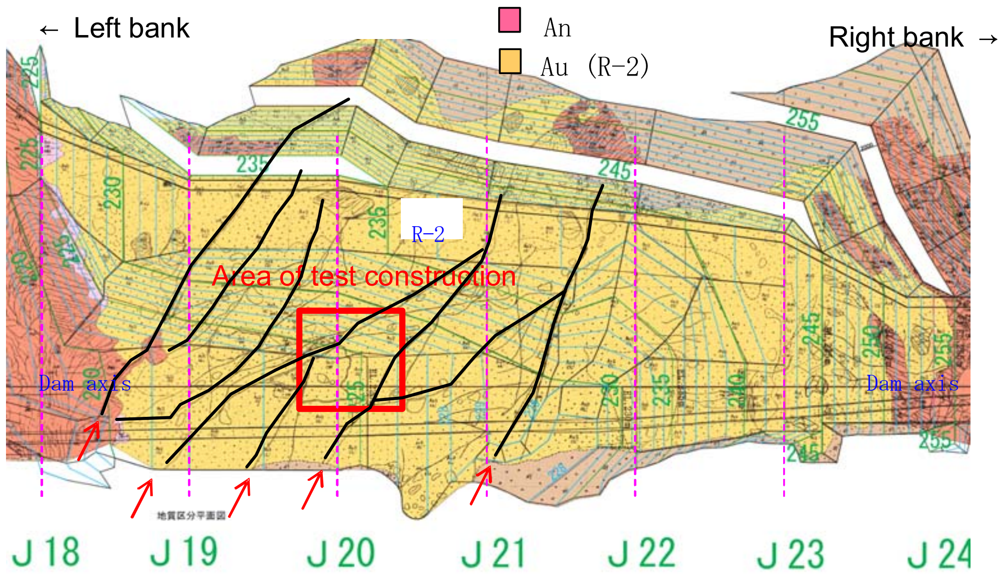


Fig. 10
Geological sketch at right bank slope (R-2)

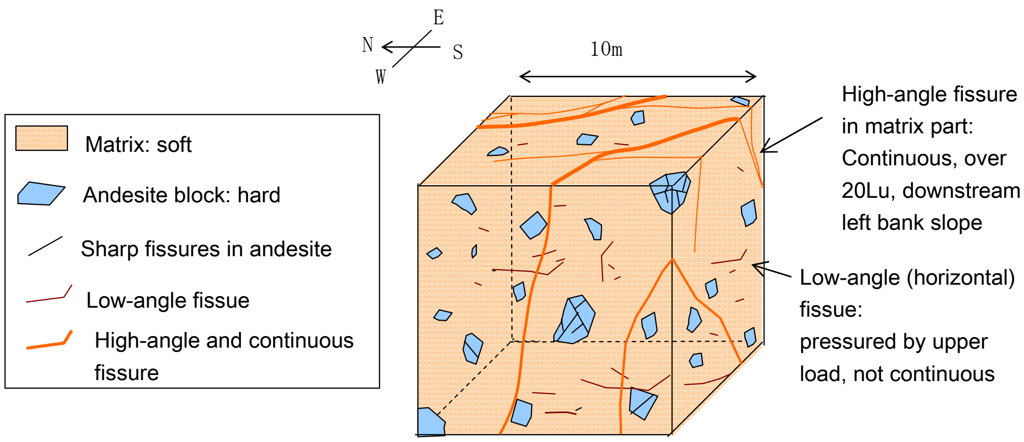


Fig. 11
Model of R-2 geology

6.2 IMPROVEMENT SITUATION BY ORDER

The relationship of holes distance and Lugeon value to cement content under the test construction with use of lattice-shaped arrangement is shown in the preceding chapter, Fig. 8 and Fig. 9. Both Lugeon value and cement content reduced significantly at secondary holes, but decreasing trend was not seen at second to fourth holes. The values in construction after fifth holes resulted in reduction to approximately 5 Lu. Eventually, it was concluded that even when construction at 1.25 meters spacings at sixth holes was implemented, it was difficult to improve the value to below about 2 Lu.

Considering that the result of Lugeon value and cement content indicates the effect of injection at previous order, the target site, which showed high permeability of 20 Lu or more before construction of grouting along with 5 m or more of continuing large fissures, seemed to be improved in values by cement fluid from the primary holes to lead to about 10Lu through construction of second holes. The reason for not lowering of Lugeon value after secondary holes may be that cement fluid covers only about 2.5 m of area in fissures of 10 Lu or so to keep the value stable without reducing Lugeon value before constructing fifth holes. (See Fig. 12). Also, construction up to at 1.25 m spacings does not reduce the value to below 2 Lu. This does not appear to be caused by continuous fissures, judging from core observation, because improvement by grouting becomes difficult even with narrow spacings due to void matrix and fine cracks, which affect permeability.

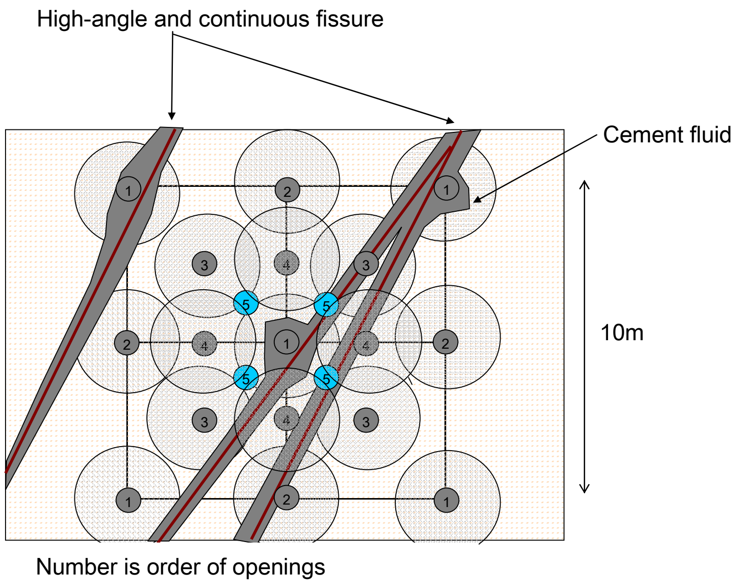


Fig. 12
Improvement of permeability

As in the above, high angle fissures which raise concerns as significant water path was effectively improved by construction of three-row curtain grouting. However, the effect was limited to 5 Lu because of void matrix part and fine cracks. Not having caused continuous fissures, it would be appropriate to lower the target level of improvement to 5 Lu because of darcy flow.

6.3 GROUT FILLING RATE SHOWN BY TYPE OF FISSURE AND ORDER

To test the hypothesis of Section 6.2, a study on the ordered filling characteristics of cement milk was conducted by test construction after fissures were divided into two types: andesite ones and matrix ones.

As shown in Fig.13, as for the filling rate, fillings into matrix are mainly verified in low order level, while many fillings are seen in andesite block as opening spacings narrow.

This result is believed to be due to the difference between the both continuities of fissures. In other words, as the fissure of andesite block continues only in its block, filling rate lowers because there is a low probability of continuity of fissure between filling holes and observation holes when the distance between holes is long. On the other hand, it is considered that high-angle fissures in matrix part are relatively rich in continuity and more cement fluid can be filled even where the distance is long.

When considering the lowering trend of Lugeon value (Fig. 8) together, most of fissures of matrix part at secondary holes are filled up and fissures of matrix part are distinguished in the area with high permeability of 20 Lu or more. In addition, construction up to 1.77 m lattice results in improvement to 5 Lu by filling up the fissures in andesite block and matrix. The fissures of matrix part do not increase by constructing 1.77 m or narrower lattice, showing the same trend as in Lugeon value. It is considered that permeability in this geology with 5 Lu or more is mainly caused by the fissures of matrix part. On the other hand, it would appear that the fissures of andesite block are not continuous and influence on water permeability is small.

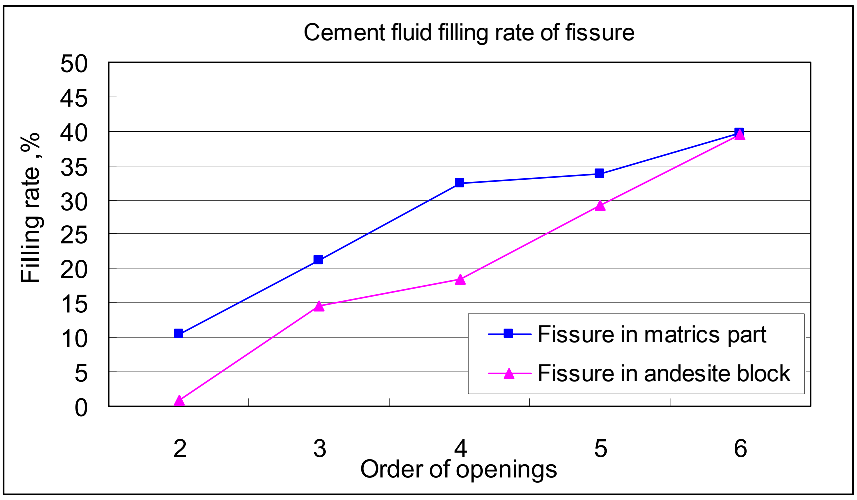


Fig. 13
Cement fluid filling rate of fissure

7. THE PLAN OF THREE-ROW CURTAIN

7.1. THE CONDITION OF GEOLOGY IN RIGHT BANK SLOPE

Topographical map of right bank slope is shown in Fig. 14. The Takenosako River flows in the shape of valley in the immediate upstream of right bank slope and the slope is sharp narrow ridge. Also, Fig. 15 is a cross section with consideration given to seepage path. The dam is located on the ridge with short seepage path of bed rock, featuring low groundwater level as shown in Fig. 4 and Fig. 15. Taking into account this feature, one row is added in accordance with the lowered target level of improvement.

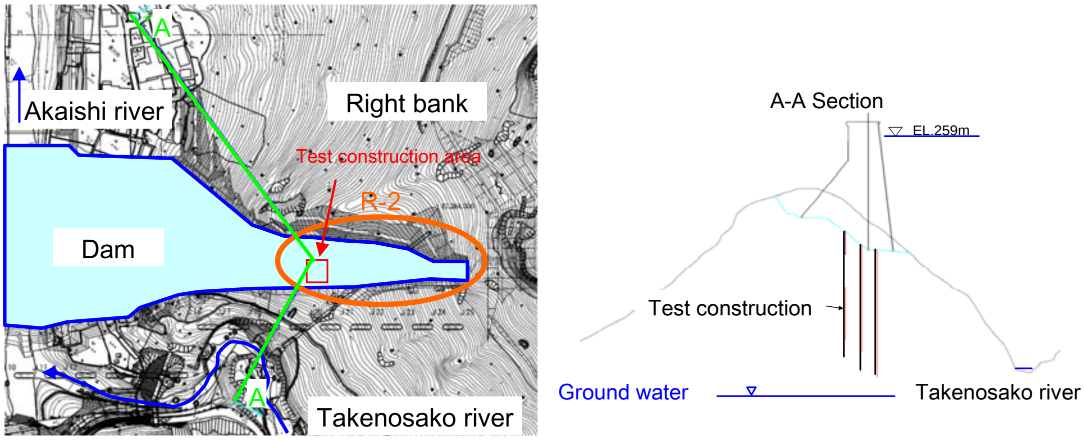


Fig. 14
Topographical map and cross section of right bank slope

7.2 DESIGN OF THREE-ROW CURTAIN GROUTING

As for autobrecciated andesite type 3 in sharp narrow ridge in right bank, it is difficult to achieve the target level of improvement, 2 Lu and 5Lu, in design opening spacings. Therefore, the target level of improvement is set to 5 Lu, which is considered as the possible limit for effective improvement in the reticular pattern at 1.5m opening spacings, to construct grouting along with formation of thick impervious zone.

7.2.1 Basic concept

① Placement : form the thick impervious zone by the placement of holes required for improvement to 5 Lu

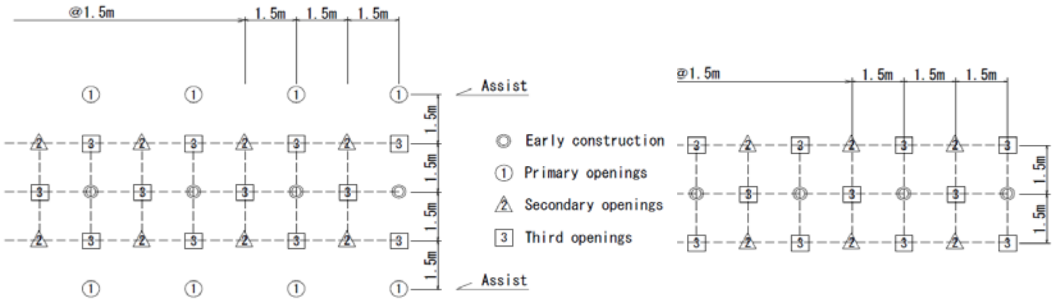
② Depth : the range of CL class of autobrecciated andesite type 3 in right bank (the range which is difficult to achieve the target revel of improvement based on the construction result)

③ Range : the range of CL class (R-2) of autobrecciated andesite type 3 in right bank (H/2 at the maximum in right bank direction, and the range which is difficult to achieve the target level of improvement based on the construction result of curtain grouting)

④ Target level of improvement : set effectively based on the early construction results and the result of test construction, and set it to 5Lu

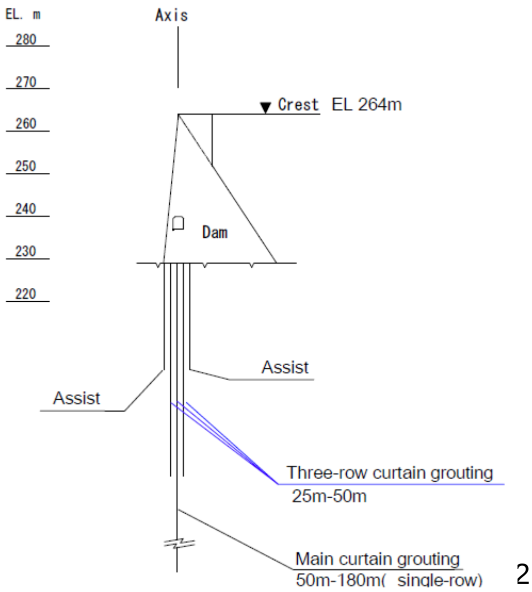
The placement of openings is shown in Fig.15.

Sectional view are shown in Fig.16.



(1) 0-25m depth (2) 25-50m depth

Fig. 15
Placement of curtain grouting at R-2



(3)Injection specifications

Specified injection pressure has low critical pressure, but initial specified pressure is injected in hope of improvement effect because there is not much unit injection cement content in Fig.9.

Table 6
Specified injection pressure

Stages (Depth,m)	1 (0-5)	2 (5-10)	3-4 (10-20)	5 (20-25)	6-9 (25-45)	10 (45-50)
Injection pressure, MPa	0.2	0.4	0.5	0.7	1	1.5

※When critical pressure occurs, critical pressure is +0.1MPa.

Mix proportion switching is the specification which was confirmed in test construction. Initial mix proportions are 1:10 （less than 10Lu）, 1:8 （10-20Lu）, 1:6 （more than 20Lu） depending on the Lugeon value and thicken up to 1:1 in stages.

7. SUMMARY

The geology of right bank slope is the shape of sharp narrow ridge and main feature is that its groundwater level is extremely low. Also, it was expected that improvement to the target level in either of 2 or 5Lu is difficult in the area where soft autobrecciated andesite type 3 is distributed thick as a result of early construction of curtain grouting. Therefore, this geology was confirmed to be able to improve to 5Lu by conducting test construction in a reticular pattern and central interpolation.

Based on the result of the test construction, the plans were changed to effective three-row curtain grouting after grouting, geographic features and geology characteristics are considered.

Three-row curtain grouting was constructed using the placement of openings of curtain grouting constructed in early construction. In addition, it was decided to construct 25m auxiliary curtain grouting to the outside area ranging from 0 to H/4.

8. IN CLOSING

Three-row curtain grouting is now (January 2010) under construction, and further consideration such as whether the volume of construction is appropriate and how to construct the additional openings are needed. Also, the treatment of water stop mostly becomes apparent only after dam impoundment is completed, and it needs continued and careful observation until first impoundment.

The grouting technical guide has been revised in 2003, and dam grouting is needed to continuously review the construction specification to construct more rationally based on each dam’s characteristic. Therefore, it is important view that if grouting is excessive or not, but it is vitally important to analyze the result of construction with a view to inadequate construction in the dams with geological challenges. This case is informative to the construction of other dams that have geologically similar problems.

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