Case Study of the Construction of Embankment Copper Dam by using Synthetic Filter Mat in an Existing Reservoir during the Normal Operation

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Abstract: In order to construct the additional concrete spillway structure in an existing dam, the specially considered embankment copper dam was designed and constructed. The copper dam was quickly constructed during the dry season using the seasonal variation of the reservoir level under the normal operation of reservoir. The sequence of the construction of the embankment copper dam was different compared to normal process of embankment dam construction. The embankment was firstly constructed as possible as quickly during dry season. And then the cut-off grouting at the top of the embankment was secondly conducted to provide the proper bonding between the embankment and the foundation. The geotextile filter mat was introduced to reduce the construction period. The dimension of the core zone was adopted widely to tolerate the heavy grouting works.

Keywords: Copper Dam, Geotextile filter, Embankment Dam, Additional spillway, Cut-off grouting.

1. Introduction

Daechung dam located in the middle of South Korea was completed in 1980 and operated for the purpose of flood control, produce of electricity, and water supply to nearby large city area. Daechung dam has 1490 million tons of reservoir capacity, 72m of height, and 495m of length. Recently, Daechung dam has been planed to increase the discharge capacity during the flood season in order to adjust the sudden heavy rainfalls due to the climate change associated with global warming. The additional large scale spillway structure to control the discharge of flood water was planed and introduced. The general feature of the spillway structure is same as the open channel which is controlled by concrete dam at the entrance of the spillway structure. It is expected that the reservoir can be operated safely and effectively with the help of the additional spillway structure.

In order to construct the concrete spillway structure, specially designed embankment copper dam was introduced. The copper dam has 18m of height and 310m of length. Existing site conditions to be affected by the reservoir operation caused several issues to be overcome. The reservoir level has been changed seasonally, such as very high at the beginning of autumn and very low at the spring season. As a result of site conditions and to overcome these difficulties, the copper dam adopted in this project has several distinguishable features compared to the normal copper dam which is used to bypass the river system during the period of the construction of main dam. The copper dam was quickly constructed during the dry season using the seasonal variation of the reservoir level. The sequence of the construction of the embankment copper dam was different compared to normal process of embankment dam construction. The embankment was firstly constructed as possible as quickly during dry season. And then the cut-off grouting at the top of the embankment was secondly conducted. This cut-off grouting is responsible for cutting off the ground water flow in the foundation as well as to provide the proper bonding between the newly constructed embankment and the foundation underlying. The geotextile filter mat was also adopted to reduce the construction period as well as to provide the proper filtering between the core zone and the shell zone. The wide dimension of the core zone was selected to tolerate the heavy grouting works to be performed at the top of the embankment. Permeability tests before and after the cut-off grouting were conducted to make sure the effectiveness of the grouting. The changes of the ground water table of the embankment and the foundation was monitor to check the performance of the copper dam during the construction period and after.

This paper provides the case study of the construction of the embankment copper dam in an existing reservoir during the normal operation. The features of the embankment copper dam to accommodate the site conditions were explained in detail. The construction sequences and the methods were explained in details. The outline of the reservoir operation and the discharge of the secondary spillway system were also presented to provide the general issues of the project.

2. Outline of the project to improve the flood discharge capacity of the Daechung Dam

In order to increase the flood discharge capacity of the Daechung dam and reservoir, the additional spillway system was introduced. The general dimension of the Daechung dam and reservoir is explained in Table 1. The location of the additional spillway in a Daechung dam reservoir is shown in Fig. 1. The Dimension and capacity of the additional spillway is shown in Table 2. The flood discharge capacity can be increased from 10,452 m^3/sec to 18,036 m^3/sec after completion of the additional spillway system.

Table 1 Dimension of Daechung Dam.

Type	C.G._E.C.R.D
Height (m)	72
Volume (m^3)	1,234
Length (m)	495
Total storage capacity (m^3)	1,490,000,000
Effective storage capacity (m^3)	790,000,000
Flood discharge capacity (m^3/sec)	10,452
Electric power supply (MW)	90

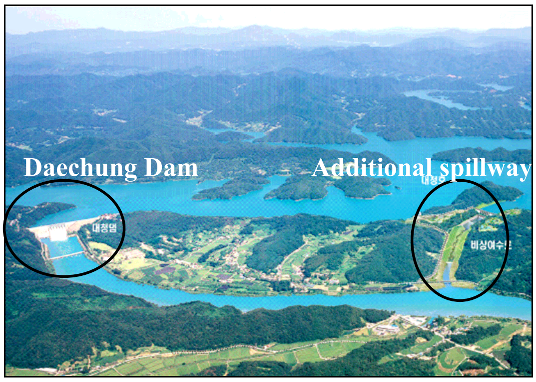


Fig. 1 Location of the additional spillway in a Daechung dam reservoir.

Table 2 Dimension and capacity of the additional spillway.

Type	C.G. Dam and open channel
C.G. Dam Height (m)	55
C.G. Dam Length (m)	280
Flood discharge capacity (m^3/sec)	7,584
Open channel length (m)	1085

3. Construction of the embankment copper dam

The embankment copper dam was quickly constructed during the dry season in 2007 as shown in Fig. 2. Total construction period of embankment itself was about 2 months. The Fig. 3 and the Table 3 explain the cross-sectional shape and the dimension of the copper dam.

The construction sequences were as follows.

1) Removal of the soft top soil: During 20 year's reservoir operation, there was a deposition of soft layer in a construction site. Only soft clayey soils were removed. Loose sandy materials were remained not to be flooded in the reservoir water, because the construction of the embankment under the reservoir level could result in poor compaction due to wet condition.

2) Construction of the embankment: the construction of the embankment was conducted as possible as quickly to complete the work before the rainy season.

3) Cut-off grouting: The MIS (Micro Injection Process System) grouting which is a kind of micro cement injection method was carried out at the top of the embankment. The considerable amount of micro cement was injected to cut-off the ground water flow in a foundation and to reinforce the contact layer in the bottom of the embankment

4) Installation of the instruments to measure the performance of copper dam was completed.

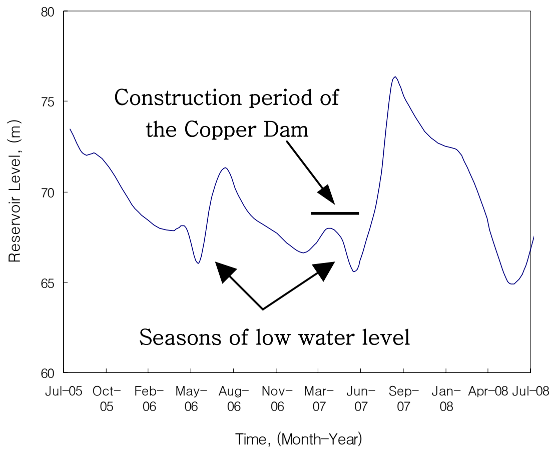


Fig. 2 Change of the reservoir level and the construction period of the copper dam.

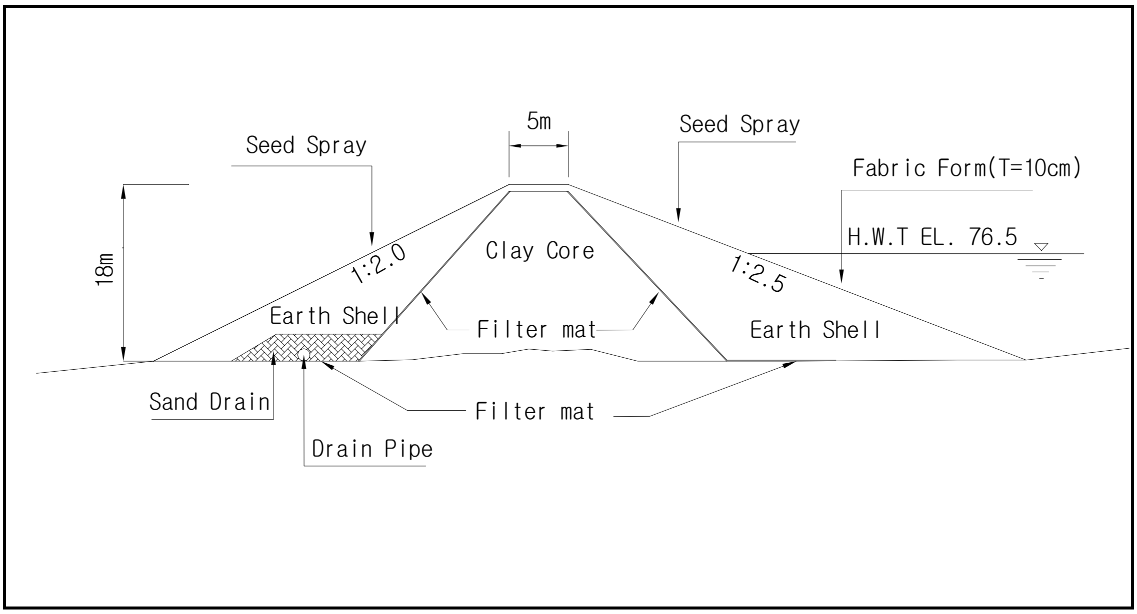


Fig. 3 Cross-section of the embankment copper dam.

Table 3 Dimension of the copper dam.

Type	Earth fill dam
Height (m)	18
Length (m)	310

The geotextile filter mat was introduced to reduce the construction period of embankment. Fig. 4 and Fig. 5 demonstrate the installation of the geotextile filter mat. Table 4 shows the properties of the geotextile used in this case study. The use of geotextile filter mat is well defined in ICOLD (1986). Heerten (1993), Christopher *et al.* (1993), and Fischer *et al.* presented their own method to design the geotextile filter. Recently, Palmeira and Fannin (2002) provided the detail reviews for the use of geotextile as a filter material. All the authors, above mentioned, provided different guidelines to determine the opening size of the geotextile. Their guidelines present the similar way in an aspect that the opening size (O_{95}, O_{98}, O_{90}, or O_{50}) of the geotextile is compared to the equivalent size of the base soil such as D_{50B} and D_{85B}.

The limitation of the use of geotextile filters in dam was also pointed out in ICOLD (1986) and ICOLD (1994). They recommend paying considerable cautions when the geotextile filter is used as critical filters in dam, because 1) the possibility of damage during the installation, 2) differential movement of the dam during and after construction, 3) clogging, and 4) long term chemical durability.

Fig. 4 Quick installation of the geotextile filter mat for the embankment construction.

Fig. 5 Installation of the sand drain and filter mat at the toe of the embankment.

Table 4 Properties of the geotextile filter mat.

	Properties	Test Method
Material	PET mat (Polyester)	KS K ISO 11058
Weight (g/m^2)	400	KS K ISO 9864
Tensile strength (kN/m)	30	ASTM D4945 KS K 0743
Elongation (%)	50	ASTM D4945 KS K 0743
Hydraulic conductivity (cm/sec)	a×10^{-1} (a = 1-9)	ASTM D4491 KS F 2322
Opening size AOS(μm)	110	ASTM D475 KS K ISO 12956

In this case study, those kinds of limitations of the geotextile were also considered. The long term effects were not considered because the embankment copper will be temporarily used during the construction of the spillway structure expected for about 4-5 years. The materials compacted nearby the geotextile was selected as relatively fine soils not to contain angular coarse grained materials.

4. Cut-off grouting: MIS grouting

The copper dam selected for this study experienced considerable amount of leakage through the layer of weathered soils in the foundation just after completion of the embankment work and before the completion of the cut-off grouting, as the reservoir level increased after finishing the dry season. In order to prevent the internal erosion and piping damage in embankment, the MIS (Micro Injection Process System) cut-off grouting was immediately introduced and installed. Two or three rows of cut-off grouting works were conducted on the top of the embankment. Table 6 summaries the grouting works.

The effect of the cut-off grouting was evaluated through the changes of the hydraulic conductivity before and after the cut-off grouting conducted at the check hole as shown in Table 7. Most of the weathered soil layer underneath the embankment fill presented considerable reduction in the hydraulic conductivity as shown in marked circles in Table 7a and 7b. The contact area between the embankment fill and the weathered soil also presented noticeable reduction in hydraulic conductivity, when the original hydraulic conductivity in that layer was relatively high.

Table 6 Summaries of the MIS cut-off grouting.

No. of row	2 or 3
Spacing of grouting hole	2m
No. of hole	531
Depth of hole (average)	28.5m
Volume injected/hole	5.49m^3
Materials	MIS SP 8000 (Micro cement)
Injection Pressure	1 - 5 (kgf/cm^2)
Water/Cement (weight)	3/1
Other materials	3% of bentonite

Table 7a Changes of the hydraulic conductivity before and after the MIS grouting.

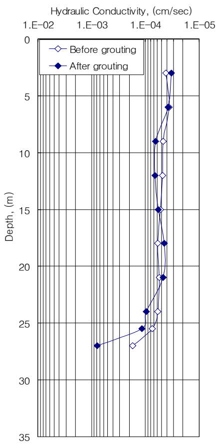
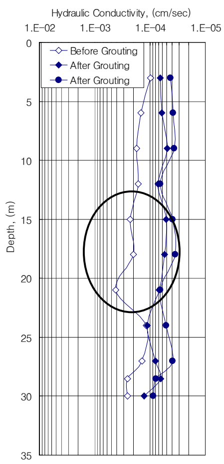
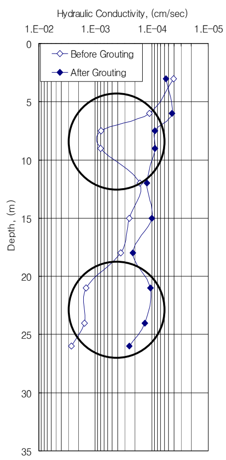
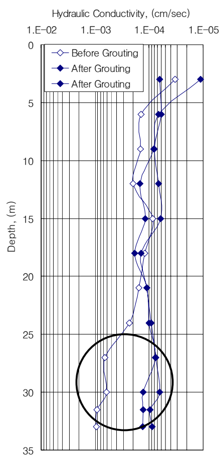
<table>
<tr><td>Test Chainage</td><td>- 60m</td><td>0m</td><td>50m</td><td>120m</td></tr>
<tr><td>Soil Profile (m)</td><td>Weathered Soil: 0-12
Weathered Rock: 12-26
Rock: 26 –</td><td>Weathered Soil: 0-15
Weathered Rock: 15-28
Rock: 28-</td><td>Fill: 0-9
Weathered Soil: 9-18
Weathered Rock: 18-24
Rock: 24-</td><td>Fill: 0-15
Weathered Soil: 15-20
Weathered Rock: 20-32
Rock: 32-</td></tr>
<tr><td>Changes of the hydraulic conductivity before and after the micro-cement grouting (cm/sec)</td><td>
</td><td>
</td><td>
</td><td>
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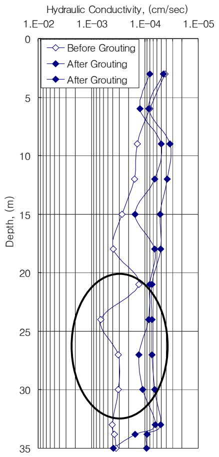
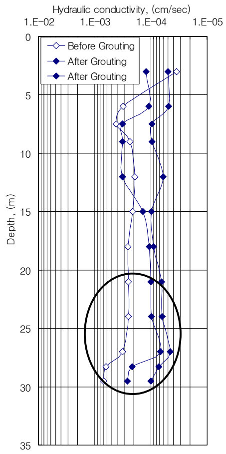
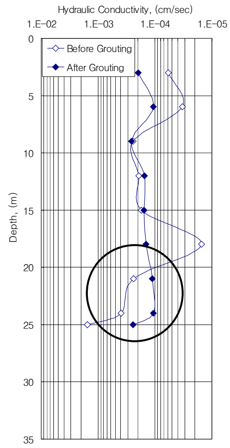
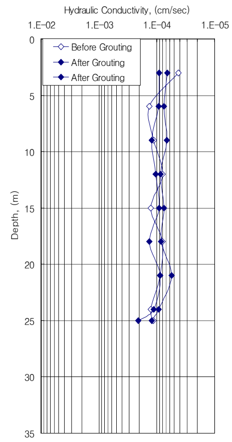
Table 7b Changes of the hydraulic conductivity before and after the MIS grouting (continued).

Test Chainage	180m	220m	260m	330m
Soil Profile (m)	Fill: 0-8 Weathered Soil: 8-24 Weathered Rock: 24-34 Rock: 34-	Fill: 0-8 Weathered Soil: 8-18 Weathered Rock: 18-28 Rock: 28-	Fill: 0-2 Weathered Soil: 2-18 Weathered Rock: 18-24 Rock: 24-	Weathered Soil: 0-13 Weathered Rock: 13-24 Rock: 24-
Changes of the hydraulic conductivity before and after the micro-cement grouting (cm/sec)				

5. Performance of the copper dam

The copper dam was experienced one flood season after the completion of the embankment as shown in Fig. 2. During the flood season and consequent high water level of the reservoir, no outstanding leakages through the embankment and the foundation was observed after MIS grouting. In order to monitor the performance of the copper dam, a set of instrumentation system was installed. The system consists of 3 inclinometers in the core zone, 3 piezometers in core zone, 3 stand pipes in downstream shell to measure the ground water table, and 8 laser targets on the embankment surface to monitor the deformation. The period of monitoring was not enough to present the trend of the performance of the copper dam, and so the data was not demonstrated here.

6. Summary and Discussion

The embankment copper dam with 18m height and 310m length was completed to provide the dry work condition for the construction of the additional spillway system in an existing reservoir, so called, Daechung Dam. In order to construct the copper dam in an existing reservoir system during the short dry season, two main options were introduced as follows;

1) Geotextile filter mat: this option reduced the total construction period as well as the construction cost. The limitations of the geotextile filter system such as clogging and long term chemical durability were not considered, because the copper dam will be removed after the completion of the additional spillway system.
2) Change of the construction sequences: this option also reduced the total construction time. The cut-off grouting was conducted after completing the embankment. This cut-off grouting was introduced to reinforce the loose contact area between the compacted fill and the weathered soil as well as to cut off the

ground water flow in the foundation.

The copper dam was experienced one flood season after the completion of the embankment and no outstanding leakages through the embankment and the foundation was observed.

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