Improvement of the Existing Dam to Control the PMF

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Abstract

In recent years, the heavy rain on a large scale is frequently occurred because of the unusual weather such as Ei Nino and La Nina. Then the dam collapses are also occurred all over the world and they cause enormous damage to human life and property in the downstream area. So, it is a desirable plan to prevent the damage to human life and property in advance of dam collapses caused by the abnormal flood. The safety estimates of the existing dams are necessary to prevent dams from the heavy rain. If there are safety problems, an establishment of countermeasures for them should be prepared immediately. In consequence, “A basic plan for the analysis of the hydrologic safety and improvement of the flood control capability (Sep. 2004)” was established to estimate the dam safety in case the unusual flood flow into thirteen multi-purpose dams and eight water supply dams for the municipal and industrial water, which are managed by the K-water.

This paper only describes Gu-cheon dam as a dam for the municipal and industrial water and it is one of the dams that the basic plan was established. Gu-cheon dam was constructed in 1987. Maximum water level was determined based on the flood frequency of 1000 years and the dam scale was determined by applying the freeboard. In this time, the study is conducted on the basis of the probable maximum flood (PMF) to establish the improvement plan for the flood control capability of an existing dam.

As a consequence of the hydrologic safety analysis, the maximum water level is estimated on El. 95.59m when PMF flows into the reservoir, and it doesn’t exceed the Gu-cheon dam crest elevation of EL. 96.0m. However, the freeboard is insufficient because it exceeds 1m in the maximum water level of El. 94.54m. The Gu-cheon dam safety for PMF was secured through the installation of the Parapet Wall on the dam body and an expansion of the existing spillway.

Key words: Flood Control Capability, Probable Maximum Precipitation, Probable Maximum Flood, Spillway, Parapet Wall

1. Introduction

In recent years, heavy rain on a large scale hits the nations all over the world because of the unusual weather such as Ei Nino and La Nina. Dam collapses are frequently occurred, which in turn leads to flood and human damages in the downstream area.

For its part, K-water needed to evaluate the safety of the existing dams and establish countermeasure plan. As part of effort to protect people's lives and property damage, "A basic

plan for the analysis of the hydrologic safety and improvement of the flood control capability (Sep. 2004)" was established, set up for old dams such as 13 multipurpose dams and 8 water supply dams.

Gu-cheon dam, one of the target dams of this plan is only described in this paper. Gu-cheon dam was constructed in 1987. Maximum water level was measured based on the flood frequency of 1000 years and the dam scale was determined by applying the freeboard.

In this time, the study is conducted on the basis of the probable maximum flood (PMF) to establish the improvement plan for the flood control capability of an existing dam.

According to the analysis result of the hydrologic safety, the maximum water level is measured on El. 95.59m when PMF flows into the reservoir, and it doesn't exceed the Gu-cheon dam crest elevation of El. 96.0m. However, the freeboard is insufficient because it exceeds 1m in the maximum water level of El. 94.54m. The Gu-cheon dam safety for PMF was secured through the installation of the Parapet Wall on the dam body and an expansion of the existing spillway.

2. Estimation of Hydrological Safety for Gu-chun Dam

(1) Present Dam Status

Gu-cheon dam, also known as central core rock-fill dam constructed in November 1987 has been about 20 years. Basin area of this dam is 12.7 ㎢, dam height 50m, dam length 234m, and total reservoir capacity 9.67 million ㎥.

Field survey was conducted many times to make the optimal plan for the improvement of flood control capability. As for upstream slope, grading is uneven on some section because of soil depletion on some of the protection stones. However, there is no corrosion and ground sink phenomenon due to storage water and connection with both sides is adequate. Moreover, stone condition of downstream slope is adequate even though there is inferior section due to some of the weathering. Dam facility is adequate because there are no slope sink, loss, down-part, trace of animal habitation and water leakage.

Especially for Gu-cheon dam, it is in charge of securing about 20,000 ㎥ water per day and supplying the municipal and industrial water to the city of Geoge as a major resources. The operational rate of its filtration plant is almost 90%. Therefore, the flood control capability improvement plan is required to consider the water level fluctuation of dam within the limitation of water supply.

(2) Hydrological Analysis

(2-1) Estimation of Probable Maximum Precipitation

PMP (Probable Maximum Precipitation, PMP) is a criteria of freeboard estimation for the safety of dam. In this project, PMP for Gu-cheon dam basin is performed on the basis of hydro-meteorological method including heavy rainfalls caused by typhoon RUSA occurred in August 2002 in Korea.

Table 1 PMP－DAD of Gu-cheon Dam Basin

Unit: ㎜

Basin Area (㎢)	Rainfall of each duration						
	1hr	2hr	4hr	6hr	8hr	12hr	24hr
12.5	173	264	429	569	685	879	1,210

(2-2) Estimation of Probable Maximum Flood

PMP for each duration is distributed by time and then applied by unit hydrograph. Parameter of unit hydrograph in the Gu-cheon dam basin is optimized on the basis of observed rainfall data of basin and runoff flow data to estimate parameter of representative unit hydrograph in the Gu-cheon dam basin. The optimal parameter is determined on the basis of a total of seven precipitation events including two of the August 2002 precipitation events, 3 of the April 2003 precipitation events and the July 2003 precipitation events, and 2 of the August 2004 precipitation events and the 2004 September precipitation events.

Table 2 Objective Storm Event for Optimization of Parameter

Events	Period of rainfall	Rainfall duration (hr)	Rainfall (mm)
Event 1	'02. 08. 08 ~ '02. 08. 14	115	351
Event 2	'02. 08. 30 ~ '02. 09. 01	40	264
Event 3	'03. 06. 18 ~ '03. 06. 20	28	281
Event 4	'03. 07. 12 ~ '03. 07. 14	18	116
Event 5	'03. 07. 17 ~ '03. 07. 19	16	96
Event 6	'04. 08. 18 ~ '04. 08. 20	15	167
Event 7	'04. 09. 06 ~ '04. 09. 08	18	177

HEC-HMS model, developed by US Army Corps of Engineers, Hydrologic Engineering Center is applied to optimize parameter. According to the review results, only 5 precipitation events are applied due to the elimination of precipitation event 6 and 7 which CN values are too low.

Table 3 Results of Optimization of Parameter

Events	Concentration Time (Tc) (hr)	Storage Coefficient (K) (hr)	Curve Number	Remarks
Event 1	3.0	3.0	79.8	
Event 2	1.0	1.0	85.0	
Event 3	1.0	1.0	83.9	
Event 4	2.0	2.0	84.4	
Event 5	1.5	1.8	84.4	
Event 6	1.2	1.5	42.5	N.G
Event 7	1.0	1.1	49.5	N.G
Select	1.0	1.0	85.0	

Huff rainfall distribution, one of the most widely used tools, is adopted and applied because it is fully reflecting rainfall trend for each region. Flood discharge for each duration are estimated by analyzing a combination of 2 sections and 3 section of cumulative probability curve obtained from Geoge observation located in Gu-cheon dam.

To study relationship between the rainfall and the runoff, HEC-1 model is used on the basis of both the presumed PMP and parameter of relationship between the rainfall and the runoff. And Probable Maximum Flood (PMF) is estimated on the basis of both the Huff second quarter and the Huff third quarter which are

divided into 3 non-excessive probability items such as 10% ,50%, 90%.

The analysis of flood routing on the basis of estimated PMF shows that the maximum water level of 520 ㎥/s on the Huff third quarter of duration 8, is the final result.

Table 4 Results of PMF Estimation for Gu-cheon Dam Basin

Duration (hr)	Peak Flood Flow (㎥/s)					
	Huff Second Quarter			Huff Third Quarter		
	10%	50%	90%	10%	50%	90%
2	366	352	323	352	349	388
4	545	462	407	473	492	548
6	616	521	463	516	529	595
8	618	524	492	507	520	610
12	595	488	488	468	482	586

(3) Review of Flood Control Capacity of Exist Spillway

Reservoir flood routing is performed on the basis of the result of hydrological analysis to determine whether the existing Gu-cheon dam could ensure the safety of dam. Reservoir maintenance plan is also performed using Auto ROM considering Gu-cheon dam is a side spillway without gates.

As a result of reservoir flood routing using PMP for each duration, it is estimated that maximum water-level is El. 95.65 m on the Huff third quarter of duration 8 , PMF is 520 ㎥/s, and maximum discharge is 503 ㎥/s as shown in Table 5 and Figure 1. Those results lead to the reinforcement to ensure the hydrological safety of the existing dam because it exceeds the original project flood of El. 94.54 m by 1.11 m

Table 5 Reservoir Routing Results when PMF inflows

Huff section	Normal water level (El. m)	Project flood (El. m)	Duration (hr)	Maximum flood level (El. m)	Peak rate of inflow (㎥/s)	Maximum discharge (㎥/s)
Second Quarter (50%)	93.00	94.54	4	95.39	462	416
			6	95.57	520	485
			8	**95.63**	**524**	**500**
			12	95.53	488	478
Third Quarter (50%)	93.00	94.54	4	95.43	492	442
			6	95.63	529	495
			8	**95.65**	**520**	**503**
			12	95.53	482	471

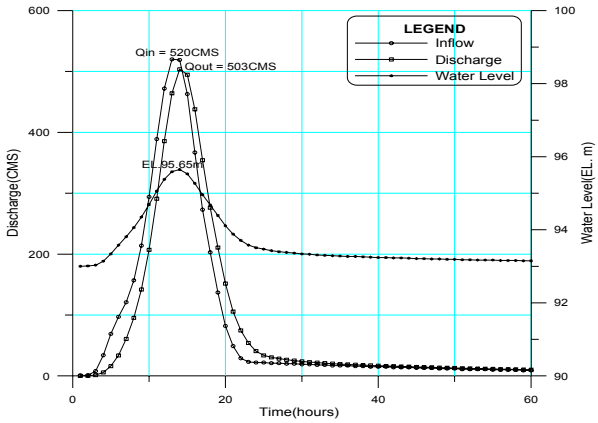


Figure 1 Flood Routing Results (Huff third quarter of duration 8) when PMF inflows

3. Determination of flood control capability plan and design

(1) Determination of flood control capability plan

The plan of flood control capability plan mainly contains structural plans such as expansion of the existing spillway or installation of new spillway. As for non-structural plans, it is still not adopted because the limited water level leads to the benefit reduction and the needs for

development of alternative water resources, and pre-release causes management problem which requires exact weather forecast accuracy.

Gu-cheon dam, also know as single-purpose dam can not control flood on its own because its major purpose is to supply the municipal and industrial water and its small basin areas makes flood discharge reaching to the dam so fast. Therefore, side spillway type without gates is considered adequate to discharge increasing flood amount from those factors.

A number of different conditions such as neighboring structures should be satisfied to establish the optimal flood control capability plan. It is considered that installation of parapet wall and Weir expansion of 10m in the existing spillway are adequate to apply on the basis of economic aspect and minimization of environmental damage.

(2) Installation of parapet wall and expansion of spillway

(2-1) Comparison with dam specification

The size of parapet wall is designed and installed considering dam freeboard in case maximum water level flows to ensure the dam safety.

The existing spillway expansion plan, set up for approach channel, chute way, is carried out from the hydrological viewpoint.

Table 6 Comparison with previous design and current design

Item	Previous design	Current design
Design flood	1000 years	PMF
Maximum water level (M.W.L)	El. 94.54 m	El. 95.41 m
Project flood level (F.W.L)	El. 94.54 m	El. 94.54 m
High water level (H.W.L)	El. 93.00 m	El. 93.00 m
Peak flood discharge (m^3/s)	266	520
Peak release discharge (m^3/s)	203	510
Spillway type	Side spillway without gates	Side spillway without gates
Weir Crest Level	El. 93.00 m	El. 93.00 m
Weir Length	50.0 m	60.0 m
Bottom level of access canal	El. 90.00 m	El. 90.00 m

(2-2) Installation of parapet wall

The results of reservoir flood routing show that maximum flood level is El. 95.41 m, and freeboard is 1.26 m. Considering the safety of dam, crest elevation of parapet wall should be projected to more than El. 96.67 m, the combination of maximum flood level and freeboard. Therefore, El. 97.00 m is evaluated as the best value of crest elevation of parapet wall considering additional water in safety sector.

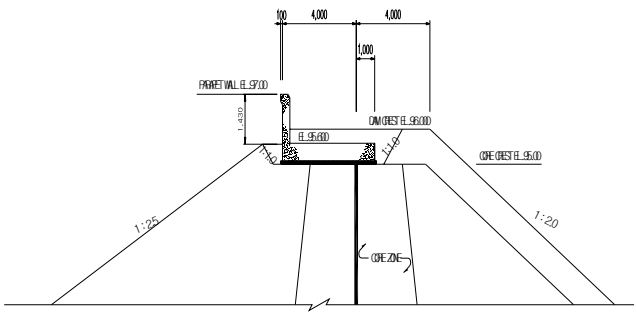


Figure 2 Installation of parapet wall at the dam crest

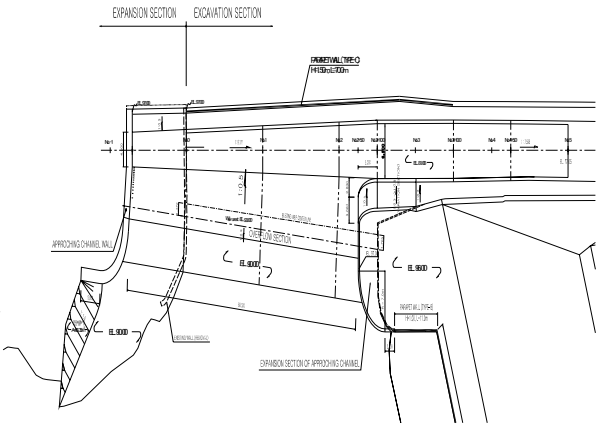
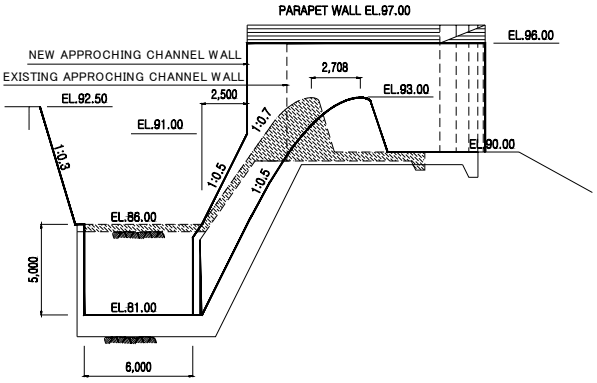


Figure 3 Detailed Plan of Spillway Channel

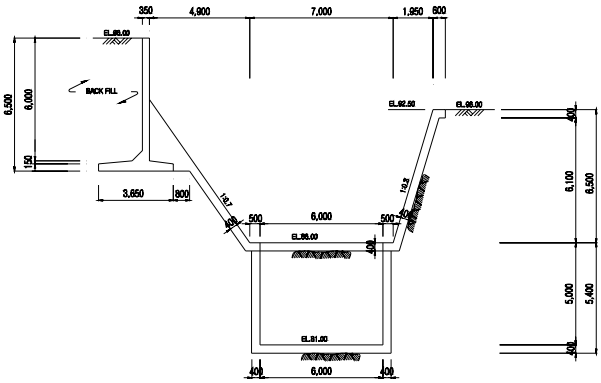
(2-3) Expansion of spillway

Improved chute way of spillway is excavated by 5.0 m without width expansion on left side. The more deeper ground is excavated, the more the existing structures are unstable, which otherwise leads to significant benefit in economic and environmental sectors. That is, with the left side of mountain expanded, slope digging can be almost eliminated, which reduces environmental damage. With no need to additional construct road and reduction of slope excavation amount, construction cost can be reduced, which is considered significantly beneficial.

The figures below show that subcritical flow condition, hydraulic limited situation should be considered to smooth flood flow down, and longitudinal channel is required to install by each case to minimize ground-digging in the economic aspect. And the size of weir section on chute section is expanded into 60 m from previous 50 m (10 m expansion).



(a) Weir and Channel Cross Section



(b) Regulated Channel Cross Section

Figure 4 Detailed Cross Section of Spillway Channel

4. Conclusions

The PMP and PMF of Gu-cheon dam are computed to estimate hydrological safety of the existing dam. According to the result, it is properly recommended that reinforcement of

lower freeboard needs to be conducted. Gucheon dam, as major water resources in Geoje area, needs to project the optimal plan to develop flood control capability of the existing dam and manage the operation of dam by reviewing flood control capability under the condition of no change in water supply capability. Therefore, in this project, installation of parapet wall and expansion of the existing spillway is designed and constructed as the optimal plans on the basis of synthetic examination such as reservoir management, stability and workability environmental quality, and construction costs.

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