The Enhancement of the Flood Control Capacity by the Construction of Emergency Spillway(Andong Dam)

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Abstract: According to the result of "The hydrological Assessment for the Safety of Existing Dams" considering the unexpected severe typhoon such as Rusa(2002) and Maemi(2003), it goes to show that the Probable Maximum Flood(PMF) for each dam was largely increased compare to the PMF when the dams were designed. The result of the assessment shows that most of dams in Korea are not safe against the newly calculated PMF. Therefore, to prevent disasters from excessive flood due to climate changes and to protect lives and property of local residents, the project for the enhancement of the flood control capacity of existing dams has been conducted. The structural methods for the enhancement of the flood control capacity of existing dams are dam heightening, upper stream-dam construction, auxiliary spillway, emergency spillway, labyrinth weir, rubber weir, siphon spillway, extension of existing spillway, watergate installation, and so on. This report mainly introduces the rehabilitation of a large dam by construction of emergency spillway using the case of Andong dam. To enlarge the flood control capacity of Andong dam, an open channel type emergency spillway was designed according to the newly calculated PMF. In this report, the progress of the project and the detailed design of the spillway are introduced. Turn-key (design-build bid) on Andong dam emergency spillway was noticed in 2007. Detailed design was completed in the late 2007 and the spillway is now under construction.

Keywords rehabilitation of a large dam, emergency spillway, PMP, Andong dam

1. Introduction

Korea has suffered from extreme flood during the last decade. The rapid increase of rainfall intensity became a threat to the safety of existing dams. Especially, in Korea, the rainfall is intensively concentrated during the summer season, which accelerates the excessive flood in summer. As a matter of fact, Korea has suffered from flooding damage in summer and water shortage in winter. To cope with the extreme floods, the standard of dam design has been changed from Frequency Flood to Probable Maximum Flood (PMF) to secure the safety of dams.

The result of the hydrological assessment conducted by Kwater in 2004 shows that the enhancement of the flood control capacity of the most of existing large dams is required to prevent disasters from excessive flood. Table 1 shows the result of hydrological assessment for the safety of existing dams. Among 27 dams, only three dams turned out to be safe. However, it was reported that other 23 dams have hydrological problems such as overflow(13 dams) and insufficient free board(10 dams). The enhancement of the flood control capacity of these 23 dams is now promoting step by step. Andong dam is one of dams which need to be rehabilitated. The PMF (Probable Maximum Flood) of Andong dam increased from 8,350 $m^3/\sec$ (1972) to 15,094 $m^3/\sec$ (2004), so when PMF flows into the reservoir, it is shown that flood overflows the dam crest. As a structural measure, the emergency spillway was selected to enhance the flood control capacity of Andong dam. This report mainly introduces the design of emergency spillway for Andong dam.

Table. 1 The result of hydrological assessment for safety of existing dams

Project Step	Name of Dam	PMF ($m^3/\sec$)			Peak Discharge ($m^3/\sec$)		Dam Crest (EL. m)	M.W.L* (EL. m)	Result of Safety Evaluation
		Dam Design		Reassessment (2004)	Dam Design	Reassessment (2004)			
Under-construction	Soyanggang	‘68	12,392	20,715	7,500	14,200	203.0	200.5	overflow
	Youngcheon	‘74	1,740	3,700	1,010	3,263	162.0	160.2	overflow
	Sueo	‘74	687	1,652	410	1,542	69.2	67.9	overflow
	Gwangdong	‘85	1,430	2,190	1,190	2,140	378.5	376.5	overflow
	Daeam	‘68	993	2,269	599	2,195	55.0	53.2	overflow
	Imha	‘84	7,550	14,800	5,300	13,350	168.0	165.8	overflow
	Daecheong	‘74	14,700	21,742	11,057	18,036	83.0	80.8	overflow
	Yeoncho	‘77	264	520	144	482	52.0	50.6	overflow
	Gucheon	‘82	266	520	203	510	97.0	95.4	insufficient free board
	Seomjingang	‘40	3,268	8,601	1,868	7,758	200.0	198.2	overflow
Completed	Dalbang	‘86	1,256	1,140	1,190	1,085	117.0	115.6	insufficient free board
Designing	Andong	‘72	8,350	15,094	5,350	11,193	166.0	163.9	overflow
	Juam (main/sub)	‘84	6,847	12,300	4,523	10,100	115.0	112.6	insufficient free board
		‘84	3,625	2,710	1,468	2,190	115.0	112.8	insufficient free board
Planning	Sayeon	‘62	1,675	2,290	930	2,120	66.4	64.4	insufficient free board
	Boryeong	‘91	3,145	3,420	2,173	2,770	79.0	76.7	insufficient free board
	Milyang	‘91	2,182	2,410	1,782	2,180	212.5	211.4	insufficient free board
	Buan	‘90	1,674	1,430	664	1,000	49.0	46.6	insufficient free board
	Unmun	‘85	4,039	7,670	-	5,910	155.1	152.8	overflow
	Chungju	‘71	26,680	35,950	20,850	29,250	147.5	146.0	overflow
	Namgang	‘87	15,800	24,650	7,000	18,000	51.0	49.4	overflow
	Seonam	‘63	17	39	-	13	32.0	30.2	insufficient free board
	Angye	‘68	167	160	12	80	46.9	44.9	insufficient free board
	Hapcheon	‘74	8,900	10,610	6,550	9,190	181.5	179.7	insufficient free board
Safe	Yongdam	‘91	10,000	10,760	7,540	6,800	269.5	265.7	safe
	hoengseong	‘90	3,658	3,610	2,505	2,720	184.0	182.3	insufficient free board
	Daegok	‘97	1,840	1,110	750	750	128.0	125.0	safe

* M.W.L: Recorded maximum water level after dam construction

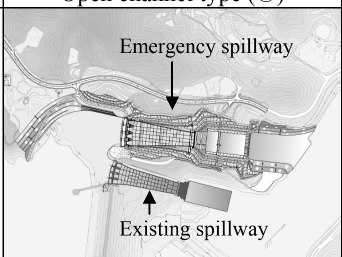
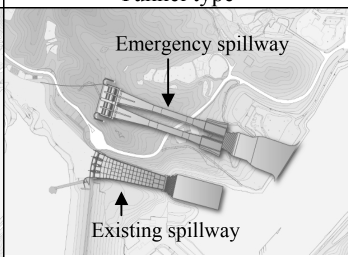
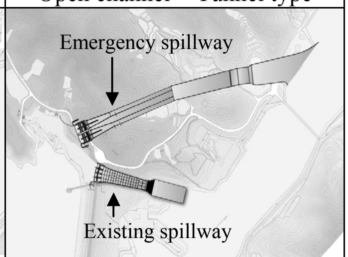
2. Type of Emergency Spillway

One of the most important facts for the design of emergency spillway is to select the optimum location of the spillway. In addition, the type of emergency spillway can be determined depend on the location. Generally, the types of the spillway can be classified into two kinds of types, which is either tunnel type or open channel type. Table 2 shows the types of spillway. Considering the hydraulic and structural stability, geomorphologic and geological condition, environmental aspect, constructability, and economical efficiency, the type of spillway should be selected. Table 3 shows the result of comparison for each type of spillway. For the emergency spillway of Andong dam, open channel type spillway was selected. Although tunnel type spillway is better than open channel type spillway in the environmental aspect, open channel type spillway was selected considering other aspects such as hydraulic stability and constructability.

Table. 2 Types of Spillway

Open channel type			Tunnel type		
Weir type		• used in multipurpose dam	Tunnel type		• open channel type in tunnel (75% of area)
Free fall type		• used in arch dam	Siphon type		• when the construction of spillway was restricted
Lateral canal type		• when over flow depth was restricted	Shaft type		• used for auxiliary & emergency spillway

Table. 3 Comparison table of each type of spillway

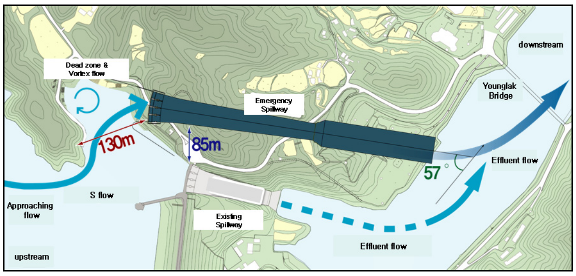
	Open channel type (⦿)	Tunnel type	Open channel + Tunnel type
Location			
Geological & Topographic	• weathering due to granite zone	• vulnerable slope zone	• vulnerable slope zone
Stability	• hydraulic stability due to straight channel	• hydraulic instability of transition zone	• hydraulic instability of transition zone
Constructability	• good constructablity due to ground working	• complicated construction of tunnel transition zone	• complicated construction of tunnel transition zone
Environment	• More environmental destruction due to excavation	• Less environmental destruction due to excavation	• Less environmental destruction due to excavation

3. Design of Emergency Spillway

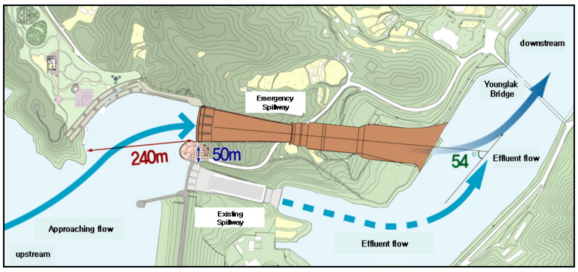
In order to rectify the problems, which were come from the Basic Plan, and to optimize the Basic Plan, computational analysis and hydraulic model experiments (1:70) were performed. For the numerical model, HEC-RAS (1D), RMA2 (2D), and FLOW-3D was used to evaluate the flow in the spillway. The results of hydraulic model were compared with those of the numerical model, which were separated into four zones such as approaching channel zone, weir zone, chute zone, and dissipater zone. Moreover, for optimum design of the spillway, the hydraulic and numerical models were performed for the basic plan. Solving the problems of the basic plan, the optimized alternative design was proposed. The numerical models for various conditions of the spillway were performed, which is not always feasible in the hydraulic models. Verified by using the hydraulic models, the optimum alternative design was proposed. In this chapter, the primary design changes between Basic Plan and Alternative Plan are introduced.

3.1 Approaching channel Zone

Through the analysis of Basic Plan, it was found that the irregular flow, flow stagnation, and flow vortex occurred due to the irregular geological features and hump of land near the approaching channel zone. To solve these problems, the location of approach channel was changed. The weir part of emergency spillway was moved 110m to the downstream. The weir part of emergency spillway was aligned with that of existing spillway. The shape of approach channel also modified. Figure 1 shows the location of approaching zone and Figure 2 shows the results of numerical analysis and experimental test for Basic Plan and Alternative Plan.

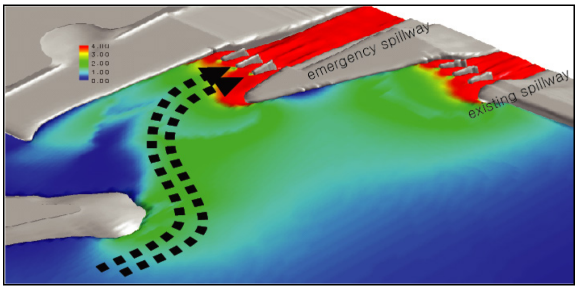


(a) Basic Plan

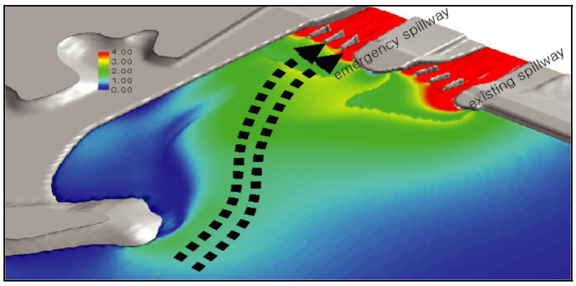


(b) Alternative plan

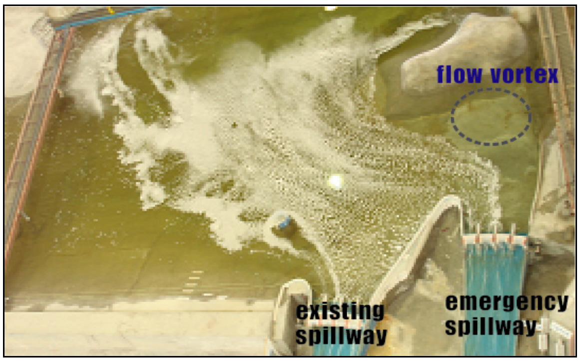
Figure 1. The location of emergency spillway



(a) Basic Plan (Flow 3D)



(b) Alternative plan (Flow 3D)



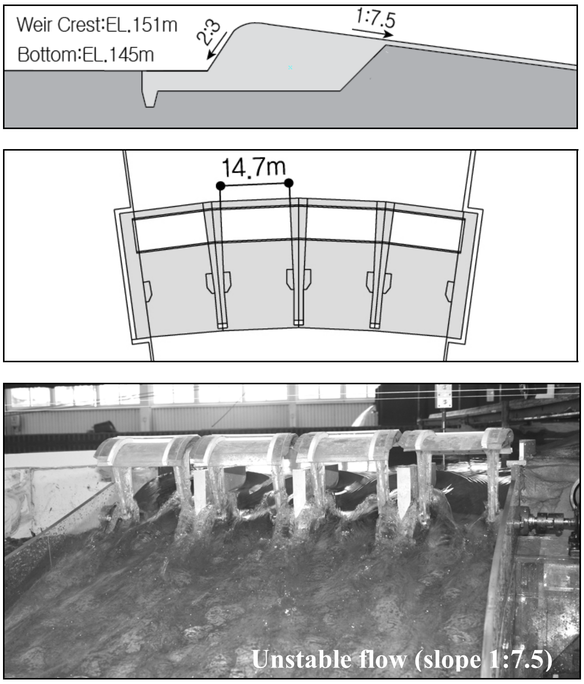
(c) Basic Plan (Experimental test)

(d) Alternative plan (Experimental test)

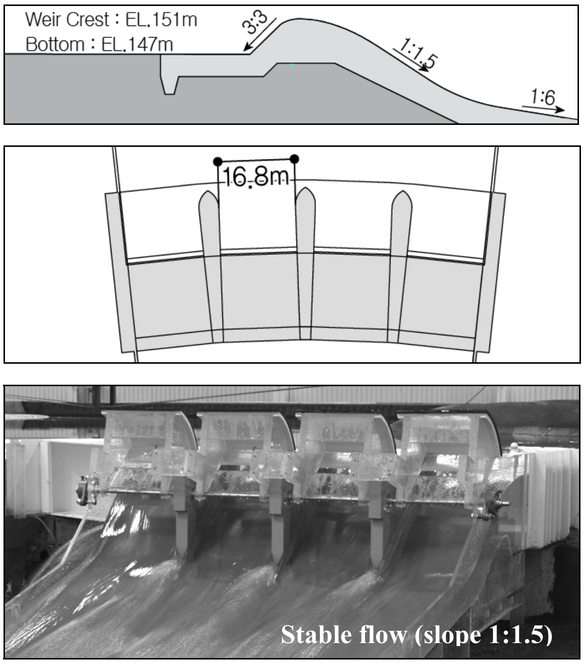
Figure 2. Comparison of Basic and Alternative Plan – approaching channel zone

3.2 Weir Part

On the authority of the results of numerical models and hydraulic experimental tests on the flow near weir part, it was found that the unstable flow appeared due to the slope of weir, the shape of pier nose, and the gate width. As an alternative plan, the gate width was increased from B14.7m × 4EA to B16.8m × 4EA, the weir slope was modified from 2:3 to 3:3, and the shape of pier nose was changed from rectangular shape to streamlined shape. The downstream slope of weir was changed from 1:7.5 to 1:1.5 to improve discharging ability.



(a) Basic Plan

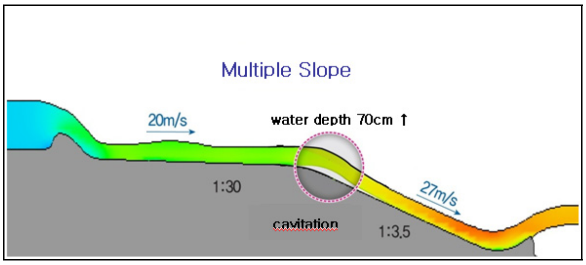


(b) Alternative plan

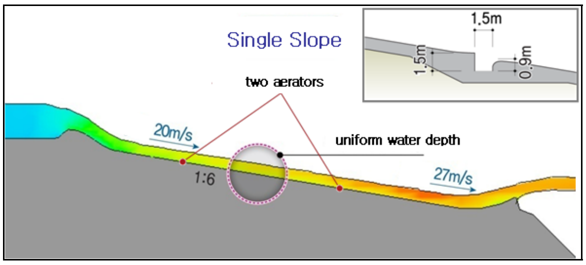
Figure 3. Comparison of Basic and Alternative Plan – weir part

3.3 Chute zone

The problems of Basic Plan in chute zone were rising water level (0.7 m) and generating negative pressure at the end of slope transition zone. In order to secure stable flow in the chute zone, the multiple slopes of chute zone were changed to single slope channel(1:30 upstream, 1:3.5 downstream → 1.6). In addition, though aerator was not adopted in Basic Plan, two aerators were adopted to protect the chute channel from cavitation. When PMF flows in the channel, the maximum water depth is 5.80m, so the height of sidewall was determined as 7.0 m.



(a) Basic Plan



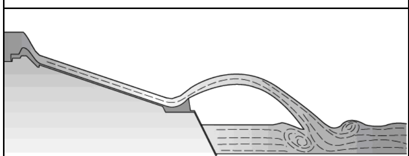
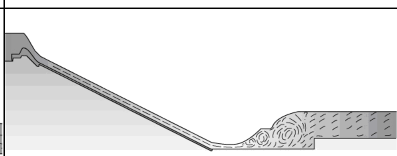
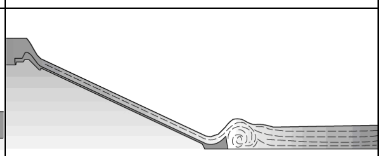
(b) Alternative plan

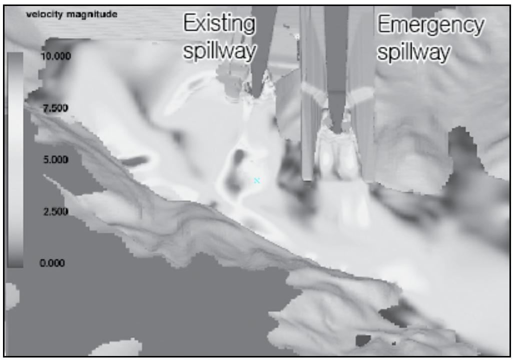
Figure 4. Comparison of Basic and Alternative Plan – chute zone

3.4 Dissipater zone

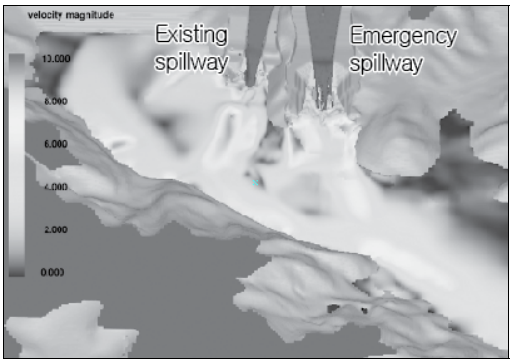
Three kinds of dissipater types were compared to choose optimum type of dissipater. The result of comparison shows that flip bucket type dissipater is better than stilling basin type and submerged bucket type in the aspects of economical efficiency, constructability and geomorphologic & geological site condition. Using the numerical models and experimental tests, the optimum flip bucket elevation and angle were calculated. The lip-elevation of flip bucket has been changed from EL. 114m to EL. 120m to maximize the effect of dissipation energy and minimize the influence of the downstream.

Table. 3 Comparison table of each type of spillway

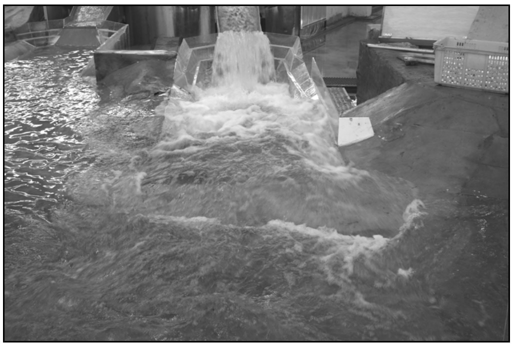
Flip Bucket Type	Stilling Basin Type	Submerged Bucket Type
		
- Stable for erosion at the stiff rock - Advantages of economical efficiency and constructability	- Need to large scale of rock excavation - Disadvantages of economical efficiency and constructability	- Disadvantages of economical efficiency, constructability and maintenance - No actual application for large dam in Korea



(a) Basic Plan (Flow 3D)



(b) Alternative plan (Flow 3D)



(c) Basic Plan (Experimental test)

(d) Alternative plan (Experimental test)

Figure 5. Comparison of Basic and Alternative Plan – dissipater zone

4. Conclusion

For rehabilitation of a large dam, non-structural and structural ways can be applied. This study mainly introduces the rehabilitation of a large dam by construction of emergency spillway using the case of Andong dam. One of the most important facts for the design of emergency spillway is to select the optimum location and the type of spillway. For the emergency spillway of Andong dam, the open channel type of spillway was finally selected based on the analysis of hydraulics, structural & geological, and environmental aspect. For optimum design of the spillway, the hydraulic and numerical models were performed for the Basic Plan. Solving the problems of the Basic Plan, the optimized alternative design was proposed. The numerical models for various conditions of the spillway were performed, which is not always feasible in the hydraulic models. Verified by using the hydraulic models, the optimum Alternative Design was proposed. Turn-key (design-build bid) on Andong dam emergency spillway was noticed in 2007. Detailed design is now under going.