Research Paper

Flip Bucket Energy Damping Model Test On Karalloe Dam Spillway

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ARTICLE INFORMATION

Article history:

Received: 21 February, 2022
Received in revised form: 29 April, 2022
Accepted: 17 May, 2022
Publish on: 30 June, 2022

Keywords:

Dam, Energy reducer, Hydraulic, Flip Bucket, Water discharge

ABSTRACT

The Karalloe Dam was built with the aim of supplying raw water, for flood control and as a tourist attraction. This dam is also a dam with a type of rock embankment with a concrete membrane (Concrete Face Rockfill Dam) which has a side spillway without a door with the Mercu model of the Mercu Ogee type. The purpose of the study was to determine the level of effectiveness of energy absorbers with variations in flood discharge that had been determined using the Flip Bucket type. The research was conducted at the Natural Hydraulics Laboratory, Department of Civil Engineering, Hasanuddin University. This type of research is experimental with a physical hydraulic model test using primary data which includes building design data. The results showed that the calculation and testing on the physical model of the spillway building with a scale of 1:50 and a simulation with a numerical model obtained the results of the length of the jump the greater the discharge, the greater the length of the jump that occurred. At the 10th return period is 37.66 cm and the QPMF return period is 73.84 cm and in model testing the effectiveness of the energy damper is obtained which shows a reduction in the average velocity from the Launcher channel to the energy absorber each period, namely Q10th 38.85%, Q20th 31.56%, Q50th 33.59% , Q100th 33.07%, Q1000th 27.29% and QPMF 30.801%.

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1. Introduction

With the rapid population growth in Indonesia, water resources are one of the most important assets. Water is the main thing for human life, whether it is for direct consumption, sanitation or to meet the needs of life, including for plant growth, livestock and electricity. One of the water structures used to optimize the use of water resources is a dam (Aghaei et al. 2021).

The hydraulic aspect of the dam is one of the important factors in planning the Energy Damping (Stilling Basin) of falling water, so that the remaining energy of the water downstream of the stilling pond is not dangerous, the planning of the stilling pond follows the existing standards (Mau 2017). The problem with this stilling pond is how far the dangers that occur at the depth of downstream scour of the dam are for riverbeds that have an outcrop (passive riverbed rock) no doubt there is scour (Pangestu 2018). The flow above the crest of the dam can show various behaviors downstream of the dam, due to the depth of the existing water. so that with this problem there will be a flow adjustment, in this process a rapidly changing flow condition will be formed. The water jump can be used as an energy absorber and to raise the water level again and to increase the pressure, so as to reduce the uplift and control forces caused by the turbulence of the water jump effect (Mau 2017).

Karalloe Dam is a dam located in the province of South Sulawesi, in the district/city of Gowa-Jeneponto and was built for the purpose of supplying raw water, controlling floods and as a tourist attraction. The Karalloe Dam is also a dam with a type of rock heap with a concrete membrane (Concrete Face Rockfill Dam) which has a side spillway without a door. The Mercu model used is the Mercu Ogee type. The overflow channel is made without a door so that when the water stored in the reservoir experiences excess volume, the water can immediately overflow (Ma'rifah and Kusnan 2018). The water that will flow later on the side spillway of the Karalloe Dam has varying volumes, depending on the rainfall that falls at any time. Then what happens is that the flow on the side spillway is influenced by the Mercu model used in the channel. As for the suitability of the Bak Lontar or Flip Bucket, it can be used if the jet emission can be tolerated and scouring is no longer a problem.

So in this study, a Flip Bucket type energy damper was used so that the residual water energy downstream of the stills pond is no longer dangerous, and the planning of the treatment pond follows existing standards. The research model was conducted at the Natural Hydraulics Laboratory, Department of Civil Engineering, Hasanuddin University.

2. Methods

The flow of this thesis research consists of six stages, starting with a search for literature related to the research theme, then followed by the formulation of the problem and research objectives. After that the determination of the hypothesis, where this hypothesis is useful for identifying research results. After that, data collection is carried out where the data that has been collected is then processed and analyzed so as to provide results and conclusions from the research.

2.1 Types Of Research

This type of research is experimental with a physical hydraulic model test, the model made is an undistorted model, in the sense that the horizontal geometry scale (nh) is taken the same as the vertical geometry scale (nv).

2.2 Data Source

Primary Data is technical data which includes building design data. The prototype parts imitated in the model include the spillway including the lighthouse, side channel, transition channel, launch channel, energy absorber with its accessories, with the model construction made of GRC (Glassfiber Reinforced Cement) material and given a coat of waterproof coating paint (Khalifehei, Sadeghi, and Azamaulla 2020). The facilities that support this research are Open laboratory measuring 7 x 15 m2 to simulate models with 1:50 and 2 scales. Water supply system and pump capacity of 150 l/s.

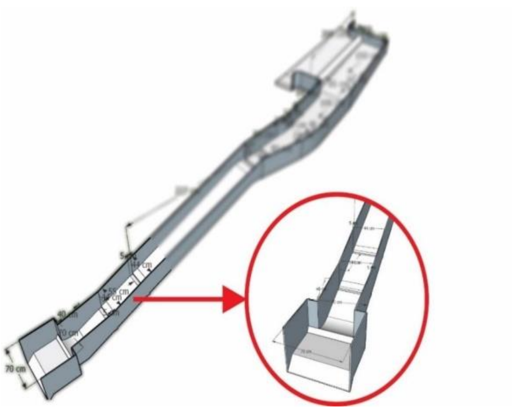

Fig. 1. Typical Model of Energy Damping for Karalloe Dam

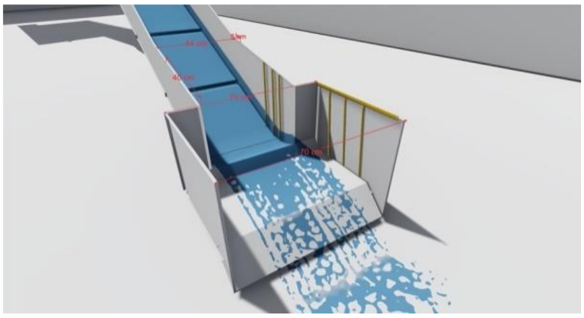

Fig. 2. Energy Reducer

Energy absorber building is the structure of the building downstream of the dam body which consists of several types, shapes and on the right and left are limited by the base wall of the dam followed by a downstream wing wall with a certain shape (Standar Perencanaan Irigasi 2016).

2.3 Design Model Testing

Design models are models based on design drawings and are intended to study and investigate design perfection (Deng et al. 2020). The series of investigations include 1) Observing the water level before and after the water level jump on various inflow designs from Q10 to QPMF and 2) Analyzing the type of flow that occurs along the channel from Q10 to QPMF based on the Froude Number (Fr) value, which is a comparison number. between the inertia force and the gravitational force along the channel spillway guide (Chow 1985).

3. Result and Discussion

3.1 Outflow on Prototype

The water level above the spillway with outflow spillway discharge in the prototype calculation with return period discharges Q10th, Q20th, Q50th, Q100th, Q1000th, and QPMF with the provisions of the scale parameters used in the study are as follows:

Table. 1 Calibration Scale Parameters

No.	Unit	Scale
1.	Long	50
2.	Tall	50
3.	Speed and time	7,071
4.	Debit	17677,67

So that the results of the calibration on the model are as follows:

Table 2. Calculation of the Calibration Scale on the Model

Repeat Period (Year)	Prototype Outflow Discharge (m^3/s)	Model discharge (lt/s)	Water Level Above Spillway	
			Model (cm)	Prototype (m)
Q_{-10th}	395,66	22,381	2,32	1,16
Q_{-20th}	482,83	27,312	2,72	1,36
Q_{-50th}	548,56	31,031	2,92	1,46
Q_{-100th}	610,40	34,529	3,12	1,56
$Q_{-1000th}$	807,40	45,673	3,84	1,92
Q_{-PMF}	1971,40	111,519	6,10	3,05

3.2 Observation of Water Level

For measuring the water level along the channel, 3 points are used with a sketch of the sampling points as follows:

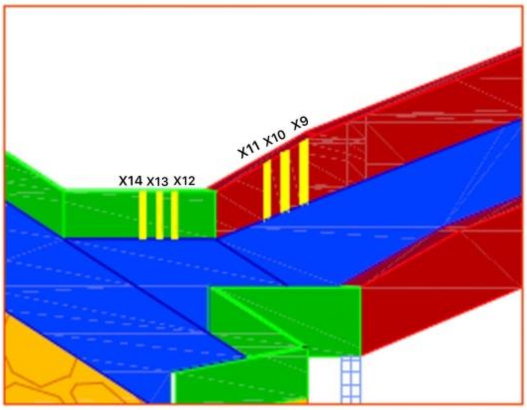

Fig. 3. Pickup Point Sketch

Fig. 4. Location of Pick-up Point on Energy Suppression Line

For the water level along the channel before the jump (X9, X10, X11) and after the jump (X12, X13, X14) the measurement uses a point gauge at six points of withdrawal based on the magnitude of the Q10th.

3.3 Flow Flow Calculation

The flow that occurs in a channel is a subcritical flow then the calculation starts from downstream towards the upstream channel, whereas if the flow that occurs is a supercritical flow then the calculation starts from the upstream direction towards the downstream channel (Rangga 1986).

Measurement of water level using a point gauge is carried out at each point, starting from the left to the right. Based on the data obtained, it can be determined the type of flow that occurs with the planned discharge in the Q-100th and Q-1000th return periods. The results of the comparison between the test model and the ANSYS analysis can be seen in the Relative Error results. Here's a summary of the results:

Table 3. Comparison Recapitulation Between Test Model With ANSYS

Canal	No sec	Speed *ANSYS* (m/dt)	Water face *ANSYS* (cm)	pressure *ANSYS* (Pa)
		Debit Q20		
Energy reducer	18	0.72	11	662.4
		Debit Q100		
Energy reducer	18	1.31	9	995
		Debit Q1000		
Energy reducer	18	1.7	10	72.63

3.4 Calculation of Flow Direction and Flow Velocity

Testing the direction and speed of flow to the spillway is carried out using the design discharge coming out of the spillway.

3.4.1 Flow Analysis Before Leap

Measuring the water level using a pitot tube before the jump, the velocity (V1) has been formulated using high pressure (hpitot).

Table 4. Condition of the water level before the jump

Debit		Condition of the water level before the jump			
Repeat Period (Year)	**Outflow (cm3/s)**	**Tma (cm)**	**V1(cm/s)**	**Froude's Number**	**Flow Type**
Q-10th	22381.90952	1.910	83.695	1.931	Super Critical
Q-20th	27312.98937	2.563	87.850	1.752	Super Critical
Q-50th	31031.23967	4.793	132.563	1.933	Super Critical
Q-100th	34529.43834	9.393	166.313	1.733	Super Critical
Q-1000th	45673.44121	12.389	206.960	1.877	Super Critical
Q-PMF's	111519.2247	17.184	241.530	1.860	Super Critical

Based on the test data before the jump, the relationship between discharge and water level is directly proportional and is depicted in the graph as follows:

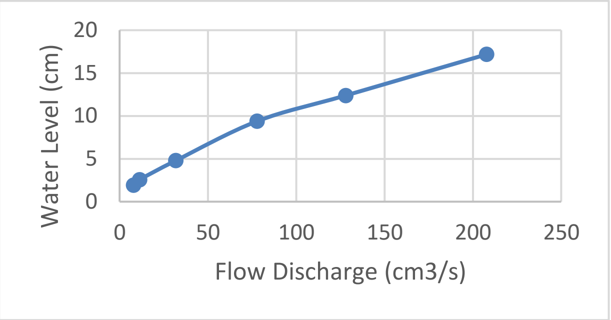

Fig. 5. Graph of Relationship between Water Level and Discharge Before Leap

3.4.2 Flow Analysis After Leap

Measuring the water level using a pitot tube after the jump, the velocity (V2) has been formulated using high pressure.

Tabel 5. Condition of the water level after the jump

Debit		Condition of the water level after the jump			
Repeat Period (Year)	**Outflow (cm3/s)**	**Tma (cm)**	**V2(cm/s)**	**Froude's Number**	**Flow Type**
Q-10th	22381.90952	7.661	53.902	0.622	Sub Critical
Q-20th	27312,98937	7.715	62.118	0.714	Sub Critical
Q-50th	31031.23967	9.010	64.467	0.686	Sub Critical
Q-100th	34529.43834	9.262	68.056	0.714	Sub Critical
Q-1000th	45673.44121	11.806	76,384	0.710	Sub Critical
Q-PMF's	111519.2247	17.100	78.770	0.608	Sub Critical

Based on the test data after the jump, the relationship between discharge and water level is directly proportional and is depicted in the graph as follows:

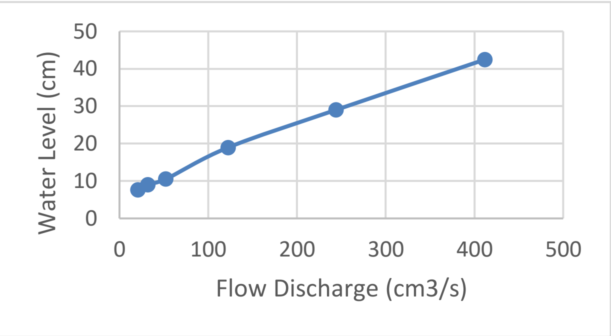

Fig. 6. Graph of Relationship between Water Level and Discharge After Leap

So that the Validation of Observation and Numerical Test Results obtained:

Table 6. Numerical Observation and Test Results

Repeat Period (Year)	Speed (cm/s)		Difference (%)
	Numerical Test	Observation result	
Q-20th	72	70.652	1.908
Q-100th	131	129.308	1.308
Q-1000th	170	167.384	1.562

From table 6. it is known that the ratio of the energy lost due to the jump with the energy before the jump during Q20th is 1.908%, Q100th is 1.308%, and Q1000th is 1.562%.

3.5 Hydraulic Jump Analysis

The hydraulic jump analysis test includes the calculation of the length of the jump, the height of the jump, and the loss of energy. So the recapitulation of the calculation is as follows:

1. Analysis of the length of the jump using the Smethane equation:

$$L = C (h2 - h1) \quad (1)$$

Where,
L = water jump length (m)
C = constant value C=6
h1 = depth of water before the jump occurs
h2 = depth of water after hydraulic jump

2. The analysis of energy loss in the jump is the same as the difference in specific energy before and after the jump using the equation:

$$Es = E_{s2} – E_{s1} =(\frac{y2-y1}{4y1y2})3 \quad (2)$$

So the recapitulation of the calculation is as follows:

Table 7. Recapitulation of Hydraulic Jump Analysis

Repeat Period (Year)	y1 (cm)	y2 (cm)	Leap Length(cm)		Leap Height (cm)	Energy Loss (cm)
			Field	Calc.		
Q-10th	1.910	7,661	64	34.50	5.751	3.670
Q-20th	2.563	9.010	67	38.68	6.447	5.058
Q-50th	4.793	10.509	74	34.29	5.716	1.747
Q-100th	9.393	18.957	96	57.38	9.563	3.988
Q-1000th	12.389	28.999	112	99.66	16.610	9.059
Q-PMF's	17.184	42.474	126	151.74	25.289	14.746

4. Conclusion

After analyzing the calculations and testing on the physical model of the spillway with a scale of 1:50 and simulation with a numerical model, it can be concluded as follows:

1. From the results of the study, the greater the length of the jump, the greater the length of the jump that occurs. At the 10th it was 37.50 cm and at the ^{QPMF} it was 151.174 cm.

2. In testing the model, the effectiveness of the energy damper is obtained which shows a reduction in the average speed from the launcher channel to the energy absorber each period, namely $Q10^{th}$ 38.85%, $Q20^{th}$ 31.56%, $Q50^{th}$ 33.59%, $Q100^{th}$ 33.07%, Q1000 th 27.299% and QPMF 30.801% .

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