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Analysis of The Stability Calculation of The D.I Padang Garugur Weam In North Padang Lawas Districtnorth Sumatera

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Abstract *- The Indonesian region is an agricultural country which causes the agricultural sector to become the main sector in supporting basic needs which is a potential value for the Padang Garurur region to become an agricultural area towards food self-sufficiency, one of the crucial issues in development at the national and global levels. The research method refers to the PU guidebook regulations. KP.06 2013, The aim of the research is to analyze and determine the stability and dimensions of the D.I Padang Garugur weir, Padang Lawas Regency against soil shear forces, overturning, landslides, earthquakes and water seepage that occur during normal and maximum water discharge. The analysis results were obtained with a design discharge of 1922.906 m3/s, a weir height of 3.36 meters, conditions when the water was normal, the overturning moment obtained fs factor 2.79 > 1.5, for soil shear it was obtained with fs 1.24 > 1.2 conditions when the water floods, the overturning moment is obtained fs = 2.09 > 1.5, it is stated that the weir is safe against overturning, the ground shear force is obtained fs 2.231 > 1.2. The conclusion states that the stability of the weir in general is greatly influenced by the physical properties or physical characteristics of the soil layers as well as the bearing capacity of the soil, as well as the control of shear, overturning, water seepage, in addition to the influence of external forces of the weir that arise during normal discharge and flood discharge conditions. it can be concluded that the D.I Padang Garugur Weir meets the stability requirements.*

Keywords *– Weir Stability, Shearing, Overturning, Soil Support Capacity*

1. INTRODUCTION

The Indonesian region is an agricultural country which causes the agricultural sector to become the main sector in supporting basic needs which is a potential value for agricultural areas, food needs which must be supported by agricultural facilities and infrastructure such as the construction of weirs to meet agricultural water needs. Increasing agriculture will increase the economic growth of the population(BAPPENAS 2020)[1]

The D.I Padang Garugur Weir, which is located in North Padang Lawas, has two left and right intake doors. This weir is a fixed weir/Ogee type spillway. This irrigation weir irrigates rice fields with an area of ± 1050 Ha. Currently, this area still lacks enough water. agricultural area(LPSE SUMUT 2023)[2]

The weir is a concrete building consisting of materials from stone masonry, gabions or cast concrete, which can be used to supply drinking water, hydroelectric power or for flushing a city.(Suhardi, Yandi . dkk 2014) [3]. Besides the availability of available water which is not sufficient for human needs, efforts must be made to achieve this fulfillment because water is the main need for life(Nofiana Dian dkk 2018) [4]

On the other hand, along with the development of Padang Lawas district, which is also due to the influence of regional changes in regional functions (especially anticipating developments with road access), the pressure for land conversion is getting stronger for industrial and residential use. This also results in shifting of agricultural land (Gessan Kurnia dkk 2020)[5]

Stability is an important requirement in Weir planning. If the safety factors are not met, it will affect the Weir body, Weirage or water seepage will also occur, as well as the danger of piping resulting in Weir safety problems which include overflow of seepage or piping and cracks in cliff slopes, earthquake loads and so on. Therefore, Weir stability is one of the requirements that must be met in the construction of a Weir (Nisa Andan Restuti. Dkk 2016) [6]

To complete the analysis of more fatal weir planning, it is necessary to use other literature which is commonly used in Indonesia for irrigation network planning or weir planning (KP 06.2013) [7]

The characteristic shape of areas with different topography is quite gentle and not rocky, so the most suitable weir plan is a fixed weir (Indrapraja, Eko, dkk, 2020) [8]

Indonesia is an earthquake-prone area. The earthquake load factor has a big influence on the analysis of weir stability. The propagation of earthquake waves which exert dynamic pressure influenced by hydrostatic forces will have a big impact on the stability strength(RaifahRekzyanti 2016)[9]

Hydrostatic pressure, especially that which occurs at peak discharge or at maximum discharge, needs to be anticipated because the weir also has a limited ability to withstand pressure, in order to avoid the weir collapsing.(Nurul Chayati, dkk 2023) [10]

The weir foundation which is located on a layer of clay (Clay) has a high permeability value, or a high level of water escape, which has a big influence on the stability or stability of the carrying capacity. then increasing stability is needed (Sulistyo Widodo 2015) [11]

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To be able to channel water from a low elevation to a higher elevation for agricultural purposes by gravity, you can use a weir which is a water structure across a river or a riverbed with the aim of raising the water level to get a waterfall, so that the water can be tapped and used for human needs (KP-02,2013) [12]

D.I Paya Garugur Weir's water source is tapped from the Onang River. This weir is one of the fixed concrete spillway weirs which functions to raise the water level so that the water can be used for irrigation water needs in the area (Adi Daning Pangestu , dkk 2018) [13]

Weir Body

A weir is a structure that is located across a river cross-section and is a type of fixed threshold whose aim is to increase the groundwater level so that water can flow to the place where it will be irrigated by the river.

Generally, Overflow weirs in Indonesia use ogee type weirs or round type weirs. This type of weir is very suitable for concrete or stone masonry. This can be seen from the fact that most of the rivers in Indonesia itself have alluvial soil which is rocky and hard. If there is a flow of water out of the weir downstream of the weir, this can result in erosion, which can result in Weirage to other structures of the weir (KP 02,2013).

Weir Width

The width of the weir is the distance between its bases (abutments), and should be equal to the average width of the river at the stable section minus the width of the gate (KP.02, 2013)

$$Be = B - 2\,(n\,Kp + Ka)\,H1.1$$

OverflowWeir

Overflow Weir

The Overflow section is the uppermost building part of the weir, where the building is useful for channeling flow from upstream to downstream. Besides that, the lighthouse also functions to regulate the high water level in the river, especially upstream of the weir.

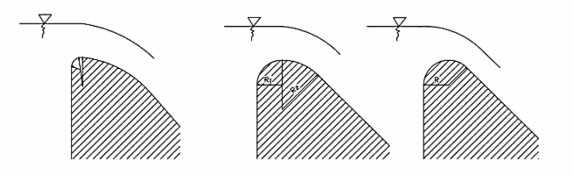

Figure 1. Weir Forms

Several technical requirements that must be needed in selecting and determining the parameters of the type of weir are as follows:

- Determining the location of the weir must take into account the topographic conditions that exist at the planned location of the weir. The weir should be planned in a straight river area.
- The gravity type weir is a type that is suitable for use on rivers with hard riverbed materials and rocks, rivers that carry chunks of wood that collide with each other or large amounts of rubbish can Weirage the weir or cause the weir to collapse.
- To determine the radius (R1 and R2) $\geq$ 0.10 m to get a larger overflow.

Abutment

The abutment also functions as a protective building or also as an embankment on the main weir. To prevent water from jumping too high, a stilling pond (water energy breaker) is used so that the water jump is not too high and avoids erosion of the foundation (Suprapto, 2016).

The Force of Weir

The forces acting or the weight of the weir building can also influence the strength or stability of the weir, as shown in table 1.

Table 1. Pressure Proportion Value

Rock foundation type	Pressure Proportion
Horizontal Rock	1,00
Steep Rock	0,67
Good Rock	0,50

Source: Director General of Public Works irrigation planning standards, 1986)

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Weir Stability

When calculating weir stability, there are several things that need to be taken into account, namely:

Control Over Shear

The weir building shifts because the horizontal force is greater than the vertical force.
formula:

$$Fk = \frac{f.H}{H} > 1{,}5$$

Overturning Control

The danger of overturning can occur in the weir due to the influence of forces, therefore it is necessary that the resultant forces acting on parts of the building on a flat plane, including up-lip forces, must push the plane on the weir. and there is no tension in any slice area. (KP-02, 2013)
The value of the weir strength against the danger of overturning can be calculated by taking into account the safety factor (FC) that has been determined by :

$$(FK) = \frac{\sum MT}{\sum MG} \geq 1{,}5$$

Control Over Eccentricity

Eccentricity that occurs in the weir can also cause overturning and shifting, therefore in planning the weir it is necessary to control the eccentricity of the center of gravity of the weir building (Hakam, Abdul. 2010) [17]

$$e = \frac{B}{2} - \left(\frac{MT - MG}{V}\right) < \frac{B}{6}$$

Control of Soil Bearing Capacity

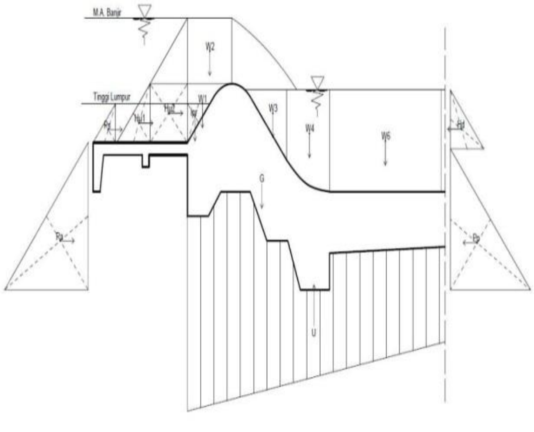
Determining the location and foundation of the weir is always planned to be layered with hard soil so that it can withstand the weight of the entire weir above it. Therefore, it is necessary to control the carrying capacity of the soil (Brajas MDAS 2 2010) using the formula:

$$\sigma_{1,2} = \frac{V}{B}\left(1 \pm \frac{6e}{B}\right) \dots$$

$$q_u = \alpha.c.N_c + z.\gamma.N_q + \beta.b.\gamma.N_\gamma$$

Control of Bottom Erosion

The process of erosion caused by hydrostatic influences on the weir is called piping hazard, which usually occurs due to water seepage through the bottom of the foundation. It is necessary to control the piping calculations under the foundation by using the vertical lane lane method which has a strength 3 times greater than the horizontal lane (Denny Ahmad F. et al. 2023) [19].



2. METHODOLOGY

The D.I Padang Garugur Dam is the source of its water from the Batang Onang river and the Sihapas river. Both rivers cross the Batang Onang sub-district. Sihapas River is a river that crosses Batang Onang sub-district which has a watershed of 367 km2. The topographic conditions around the weir are not steep (Flat) with elevation at the river bed, the weir is planned to be located on a relatively straight river body (Sulistyo Widodo et al (2015) 20
The relative elevation of the Sihapas River is +180 to +181 of the Sihapas River which is downstream of the existing free intake of the Sihapas River. The weir axle is planned at coordinates + 551804.00 N and +147506.00 E. The average width of the river around the weir is ± 35 meters.

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3. DATA COLLECTION

How to collect primary and secondary data on planned flood discharge, planned flood discharge data, soil testing data taken from related agencies such as Public Works and planning consultants

4. RESEARCH STAGE

Stages of data collection in achieving the objectives of this research, the stages are carried out as follows:
The first stage, determining the problem is done after studying the problem to be researched or evaluated
The second stage determines the background and phenomena of the problem that will be studied to obtain an overview of the research
The third stage is collecting primary or secondary data which is collected in a systematic measurable manner for analysis in order to provide optimal information.
The fourth stage is data processing and discussion
Fifth stage Data analysis and weir calculations refer to (PU.KP.02 2013 guidebook) while channel planning analysis refers to (PU.KP.06.2013 guidebook)

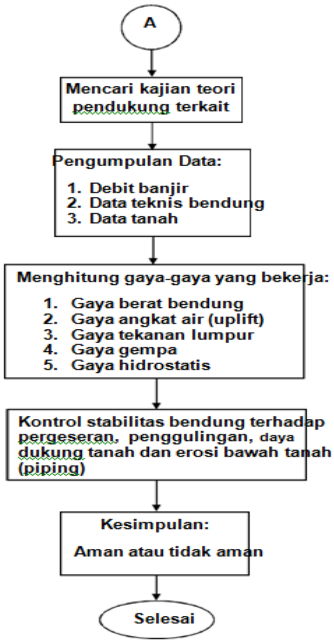

Figure 2. Research Flow Chart

5. DISCUSSION

High try Water Above Overflow

Table 2. Upstream H height using trial and error

H (meter	*Trial Error m3/det*
5	704.361
5,5	810.035
5,77	868.912
5,65	867.811

Source: Data Analysis 2023

Water Height Downstream of the Weir

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Table 3. Downstream H Height Using Trial and error

H	A	P	R	C	V	Q
1,500	112,875	78,408	1,440	47,228	16,797	1.895,970
1,510	113,650	78,444	1,449	47,081	16,906	1.921,357
1,515	114,038	78,462	1,453	47,008	16,960	1.934,114
1,511	113,728	78,448	1,450	47,066	16,917	1.923,905

Source: Data analysis, 2023

Determining Stilling Pool Type

The stilling pond is part of the downstream of the weir which is useful for overcoming the turbulence of the weir waterfall, especially during flood waters. Type IV vlugter stilling pond (Mutia Sasra Olga P et al. 2022)
Fr1 = 2.134 > Fr2 = 0.751, a stilling pond is needed. Fr1 < 4.5 using a Vlughter type stilling pond (Adi Daning P. et al 2016)

Seepage Line Length

Cw=(Lv+1/3Hu)/Hw=Lw/Hw=39.10/12.29=3.18 m
Design Cw > Existing Cw → 3.18 > 2.76 (safe)
ΔH = 19.36 -12.29 = 7.07 m
Total of calculations
Cw x H = 3.18 x 12.29 = 39.08 m
Available length = Lv + 1/3 LH = 27.67 + 11.43 = 39.10 m
So no face flooring is required

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Analysis of the forces acting on the weir

Stability Analysis in Normal Water Conditions

Table 4. Resume of Normal Condition Styles

	NcStyle Force	Force		Moment	
		H	V	Gravity Wall	Holding Force
		(Ton)	(Ton)	(Ton.m)	(Ton.m)
1	Force of own style		-276.15		-3404.64
2	Earthquake Effect (k)	27.62		193.01	
3	Force of Mud Pressure (Hh)	5.318		72.431	
4	Force of UP Lift Pressure (U)		155.01	849.50	
5	Water Pressure (WH)	5.645		76.885	
6	Water Force (WV)		-1.496		-29.411
7	Effect of Earth Pressure	3.635		39.344	
	Amount	42.218	-122.64	1,231.17	-3434.05

(Source: Data analysis, 2023)

a. Overturning

$$Sf = \frac{\sum MT}{\sum MG} > 1,5$$
$$= \frac{3.434,05}{1.23,17} > 1,5$$
$$= 2,79 > 1,5$$

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b. Slidding

$$Sf = fx\frac{\sum RV}{\sum RH} > 1,2$$
$$Sf = 0,75x\frac{122,64}{41,22} > 1,2$$
$$\text{Sf} = 2,231 > 1,2$$

c. Soil Bearing Capacity

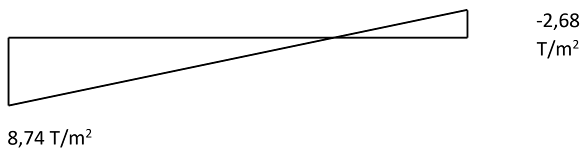
Qult = c. Nc + γ. Nq + 0,5.γ.B.Nγ
= 1 x 15,78 + 1,7 x 6,2 + 0,5 x 1,7 x 7 x 4
= 50,12 ton/m^2

$\sigma = \frac{qult}{Sf} = \frac{50,12}{4} = 12,53$ t/m^2

e $= \frac{65}{2} - \frac{3.434,05-1.231,17}{122,64} < \frac{65}{6}$

Σmin =-2,68ton/m^2<12,53ton/m^2

Σmaks =8,74ton/m^2 <12,53ton/m^2



Stability in Flood Water Conditions

Table 5. Summary of Flood Water Condition Styles

No	Force Factors	Force		Moment	
		H (Ton)	V (Ton)	Overtuning (Ton.m)	Holding (Ton.m)
1	Influence of own weight(G)		-276.15		-3404.64
2	Effect of earthquake (k)	27.62		193.01	
3	Influence of UP Lift Pressure (U)	5.32		72.43	
4	Effect of water pressure (WH)		266.38	1521.26	
5	Effect of water pressure (WV)	23.08		324.11	
6	Influence of Mud pressure (Hh)		-88.80		-1080.34
7	Effect of Earth Pressure	3.64		39.34	
	Total	59.65	-98.57	2150.16	-4484.98

(Source: Data analysis, 2023)

- Overtuning
  - $\text{Sf}=\frac{\sum MT}{\sum MG} > 1,5$
  - $= \frac{4.484,98}{2.150,16} > 1,5$
  - = 2,09 > 1,5

- Slidding
  - $Sf = fx\frac{\sum RV}{\sum RH} > 1,2$
  - $Sf = 0,75x\frac{98,57}{59,65} > 1,2$
  - Sf = 1,24 > 1,2

- Soil Bearing Capacity
- Length of weir foundation footing(L) = 35,20 m

e $=\frac{B}{2} - \frac{\sum MT-\sum MG}{\sum RV} < \frac{B}{6}$

$= \frac{35,20}{2} - \frac{4.484,98-2.150,16}{98,57} < \frac{35,20}{6}$

= 8,81< 10,83

$\sigma = \frac{RV}{L}x\left(1 \pm \frac{6xe}{L}\right) < \sigma = 12,53$ t/m^2

$= \frac{98,57}{35,20}x\left(1 \pm \frac{6x8,81}{35,20}\right) < \sigma = 12,53$ t/m^2

Σmin =8,01ton/m^2 <12,53ton/m^{2}Σmaks =-2,40ton/m^2<12,53ton/m^2

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6. CONCLUSION

Analysis of calculations during normal water conditions, the overturning moment was obtained by a Safety factor (fc) of 2.79 > 1.5, and for soil shear, it was obtained with fc = 1.24 > 1.5, while for conditions during flood water the overturning moment was obtained by SF 2 .09 > 1.5, and for soil shear, fc = 2.231 > 1.2. declared weir stability safe (OK)

Q plan of 1922.906 m3/s obtained dimensions and weir height of 3.36 meters from the calculation of stability values in both rolling, sinking and piping conditions as well as carrying capacity stability values can be declared safe, this is in accordance with laboratory data.

Analysis of the stability of the weir in general is greatly influenced by the characteristics of the soil layer as well as the bearing capacity of the soil, as well as the control of shear, overturning of water seepage and the influence of forces that arise when discharge conditions are normal, the flood discharge of the DI Padang Garugur weir has met the stability value.

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