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Research Paper

Study on the Effectiveness of Earth fill Construction at the Lempake Dam Using Plaxis 2D Software

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ABSTRACT: *The construction of the embankment type dam is built through a process of stockpiling soil material which is formed with a certain slope and height as well as the selection of a weir body zone that is adapted to the soil conditions in the area. This can affect the stability of the dam body, especially during flood and earthquake conditions. If these stability requirements cannot be met, it will have an impact on the safety of the reservoir. To assess the stability of the Lempake Dam, Plaxis 2D software was used and then reviewed under the following conditions: normal water level, flood and earthquake water level, and rapid drawdown conditions. The data used as support in this study include topographic maps, hydrological analysis, analysis of water availability, soil data and an overview of earthquake zones. After hydrological analysis, the flood discharge for the 1000 year return period is 580.09 m3/second, the effective storage capacity is 0.43 x 106 m3. The results of the stability analysis of the Lempake Dam using Plaxis 2D software Version 20 are quite safe. When the normal water level is SF = 3,414, when the flood water level and earthquake is SF = 2,984 and during the rapid drawdown SF = 2,819.*

KEYWORDS: *Dam, Lempake, Stability, Plaxis 2D*

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I. INTRODUCTION

An embankment dam is a natural dam formed by the blockage of a river in large quantities material from debris flows, landslides, or avalanches [13], [1] and [9]. Backfill type dams have been built quite effectively in Indonesia for the provision of irrigation water, raw water and flood control since decades ago. The embankment dam has a broad base so that the load that must be supported by the dam foundation is relatively small. In planning the embankment dam is built through the process of stockpiling soil material which is formed with a certain slope and height as well as the selection of the weir body zone that is adapted to the soil conditions in the area. This needs serious attention, because it will affect the stability of the dam body. Stability is one of the requirements that must be met in the construction of a weir, where if the stability requirements are not met, it will have an impact on the safety of the weir which includes settlement, leakage, seepage, landslides, erosion and cracks. A dam landslides due to repeated earthquakes [7], extreme climate hazards [4] and [5], or snowmelt [3]. So the stability of the dam body needs to be reviewed under several conditions, namely, newly built conditions, normal water levels, flood and earthquake water levels, and rapid drawdown conditions. For the purposes of studying the stability of the Lempake Dam, data such as hydrological data, hydraulics data and soil testing data are needed in the laboratory to field tests.

These data are intended as supporting material for analyzing the stability of the Lempake Dam, which is an important factor for the safety and strength of the dam body. To find out the safety factor in accordance with the minimum requirements, it is necessary to analyze the stability of the dam body which can be modeled directly according to the conditions of the soil and the body of the dam. PLAXIS was found to be more reliable than the boundary balance method for evaluating safety factors and for performing parametric analysis [11] & [2] introduces a finite element method for performing strain calculations of a two-dimensional plane in the study and analysis of dynamic response in an embankment. Soil loading modeling can then be used to calculate valid predictions, especially when static and dynamic loading and is able to obtain outputs that can be used for embankment dams [6]. By examining a sensitivity parameter, it is important that the overall stability of an embankment type dam can be obtained through this study. By using the PLAXIS software, it will be more precise in the parametric sensitivity analysis of a structure [11]. The behavior of the dam under seismic loading is studied by analyzing the effective stresses and displacements. This analysis through the finite element method makes it possible to study the behavior of the dam by considering changes in stress, strain, acceleration and displacement at different locations in the dam body. The analysis was carried out using the Plaxis 2D computer application version 20 based on the Finite Element Method under 3 conditions, namely: normal, flood and earthquake water levels, and rapid drawdown conditions.

II. LITERATURE REVIEW

In calculating the regional average rainfall can use the Algebraic Average Method. To analyze the design rainfall used frequency analysis, then by considering the statistical parameters it can be determined what distribution will be used. The nature of the statistical parameters of each theoretical distribution can be seen as follows:

a. Normal Distribution : $Cs = -0.05 < Cs < 0.05$ and $Ck = 2.7 < Ck < 3.3$
b. Log Normal Distribution : Cs = 3.Cv
c. Gumbel distribution: Cs = 1.139 and Ck = 5.402
d. Pearson Log Distribution: Cs and Ck not mentioned above (more flexible)

Analysis of water availability in this final project uses the Fj Mock Method. This method assumes that some of the rain that falls will be lost as evapotranspiration, some will immediately become direct run off and some will enter the soil (infiltration). The FJ Mock method is obtained by entering the calculation of monthly rainfall data, evapotranspiration and other parameters, resulting in a monthly flow rate. The curvature of the reservoir capacity is used to determine the total reservoir volume based on topographic data. This calculation requires a height difference (contour) of 1 m each. Find the surface area of the inundation bounded by the contour line. Then find the volume bounded by two successive contour lines using the volume equation. The maximum water level of the reservoir must be calculated accurately using the flood tracking formula. By knowing the maximum surface height of the reservoir water, it is possible to find the most optimal dam height in a safe condition against the risk of flooding. One of the methods described here is a step-by-step method. For subsurface investigations, laboratory tests or direct investigations in the field using the SPT (Standard Penetration Test) can be carried out. Unknown soil parameters from laboratory test results can be searched using empirical formulas or with correlation tables

a. Slip Resistance
b. Resistance to rolling
c. Analysis of earthquake acceleration
d. Fast Drawdown Analysis (Rapid Drawdown)

Finite Element Method or finite The finite element method is a model based on the principle of discretization, namely the division of a system structure, mass, or solid object into smaller elements. The finite element method can be used to calculate the load distribution that occurs on the element such as deformation and stress. Plaxis is a program in the geotechnical field that uses the Finite Element Method for geotechnical applications. Another important aspect of dam design is that hydraulic fracturing [10] due to seepage through the dam [14] causes leakage or failure of many embankment dams [12] and it occurs in low permeability materials such as the dam's dense clay core [8]. In modeling the geometry of the geotechnical structure, it is formed based on the components, namely points, lines, and clusters. After creating the geometry, the finite element modeling can be analyzed based on the composition of the clusters and lines in the geometry modeling.

III. METHODOLOGY

Administratively, the research location is located in Lempake Village, North Samarinda District, Samarinda City. Geographically, it is located at 0° 24' 32.50” South Latitude and 117° 11' 34.43” East Longitude. The location of the dam is on the Karangmumus River, Karangmumus watershed, Mahakam WS. Some of the data needed include Topographical Data and Hydrological Data. Topographic data is a topographic map and a map of the location of the area, while the hydrological data used as a hydrological calculation is rainfall data obtained from the Sei Siring Rain Station for 20 years. There is also climatological data including humidity data, temperature/temperature data and wind speed data including water demand data. The water demand data is obtained from the calculation by adding up the raw water demand data, evaporation and clean water. Soil data obtained from the results of laboratory tests, besides that it was obtained from empirical formulas and correlations. Review of the condition and classification of earthquake zones in the Lempake Dam project site area, to determine the extent of the influence of the earthquake zone on the Lempake Dam building.

Figure 1: lempake dam layout.

IV. RESULTS AND DISCUSSION

Analysis of rainfall data is used to obtain the maximum rainfall which is then used as a calculation of the planned rainfall. To get the maximum rainfall using the Thiessen Polygon Method, calculation steps are carried out, the following are the rainfall results using the Thiessen Polygon Method**:**

Table 1: The results of calculating the maximum daily rainfall using the Thiessen Poly Polygon method

No	Year	Rainfall Max
1	2000	70
2	2001	135
3	2002	80
4	2003	96
5	2004	97
6	2005	81
7	2006	99,5
8	2007	80,7
9	2008	86
10	2009	91
11	2010	82,3
12	2011	71,7
13	2012	80,2
14	2013	128,5
15	2014	103,5
16	2015	63
17	2016	133,2
18	2017	90,6
19	2018	78,7
20	2019	120

Analysis of the frequency and distribution of design rainfall is used to obtain statistical parameters in order to know the type of distribution that is in accordance with the rainfall data. Parameter test results can be seen in the table below:

Table 2: Results of statistical parameter tests for rainfall data

Average (X)	93,73
Standard Deviation (S)	20,96
coef. Swelling (Cs)	0,82
coef. Kurtosis (Ck)	-0,19
coef. Variation (Cv)	0,22

From the results of statistical parameter tests, then based on the requirements of each type of distribution, it can be concluded that the appropriate data is the Pearson Log distribution. To simplify the calculation of the planned rainfall using the hydrognomon application, the process is presented in Figure 2.

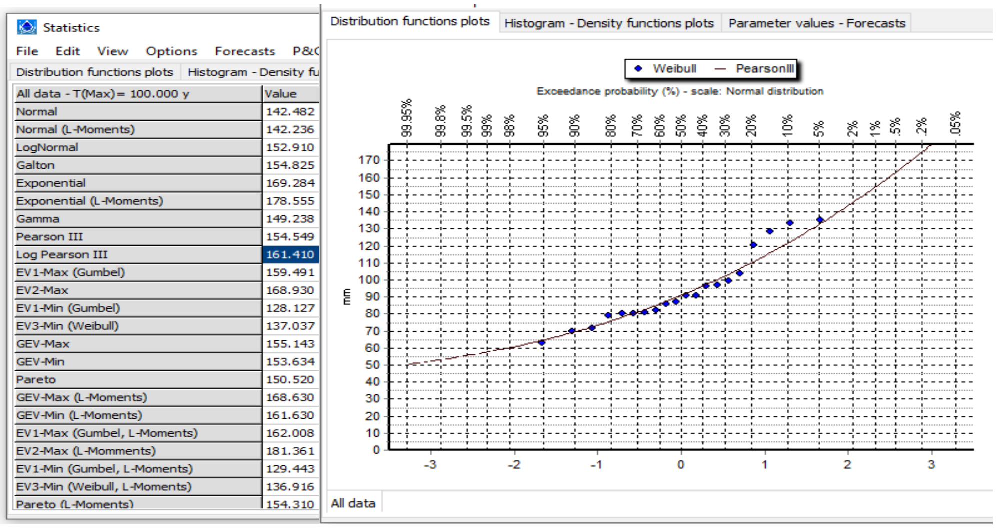

Figure 2: calculation of planned rainfall using the hydrognomon method

The hydrological data used to estimate the design flood or mainstay discharge using frequency analysis may not necessarily match the selected distributions. For this reason, it is necessary to test the distribution of fit using 2 systems, namely the Smirnov Kolmogorof test and the Chi - Square test. In the second test the Log person Type III distribution meets the compatibility test requirements, it can be seen in the following table:

Table 3: Conclusion of Distribution Fit Test

Smirnov Kolmogorof Test				
A	D critic	Value	D_{max}	Result
0,2	0,230	>	0,084	OK
0,1	0,260	>	0,084	OK
0,05	0,290	>	0,084	OK
0,01	0,360	>	0,084	OK
Chi – Square Test				
a	X^2 table	Value	X^2 calc	Result
5%	5.991	>	0,5	OK

The selection of the duration of the rain with its distribution pattern greatly influences the calculated design flood results. The same rainfall distribution with a long duration will result in a lower flood peak compared to that distributed with a short duration. The rainfall data used to calculate rainfall with various return periods is the annual maximum daily rainfall. This results in the rainfall obtained is rainfall per 24 hours. Determination of the distribution and duration of rain is carried out by observing hydrographs and hourly rain data. The recapitulation of flood discharge calculations can be seen in the table below:

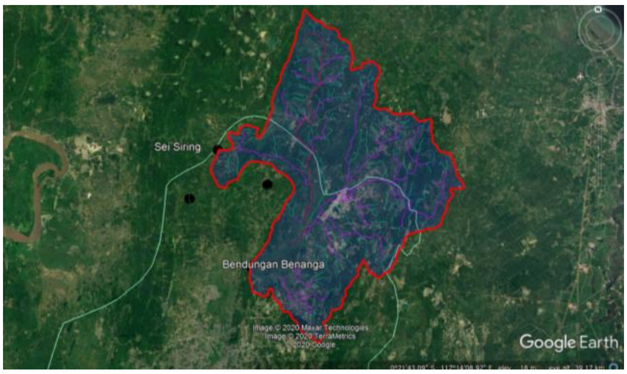

Figure 3: lempake dam watershed

The difference in the data entered for HEC-HMS modeling after calibration lies in the rainfall data for the time period used, which is for 10 years starting from 2010 to 2019, the CN value obtained from calibration is 95 and the Initial Abstraction (Ia) value is 0. ,11.

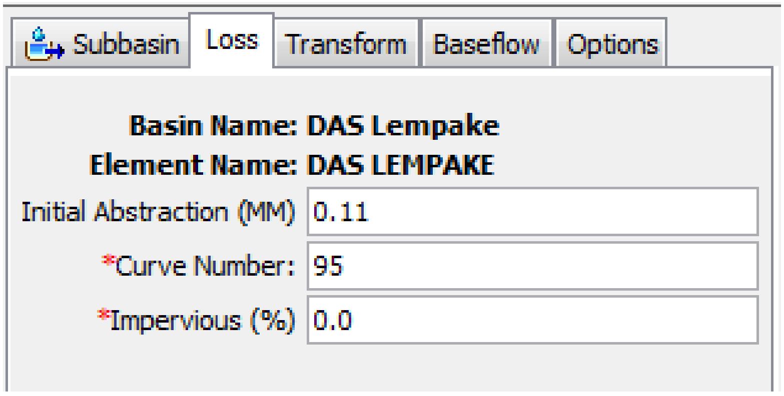

Figure 4: CN and Ia values are in accordance with the calibration results.

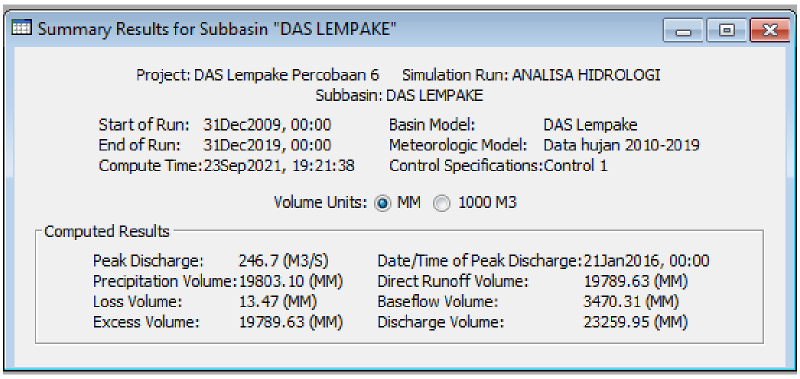

Figure 5: modeling results for 10 years after calibration

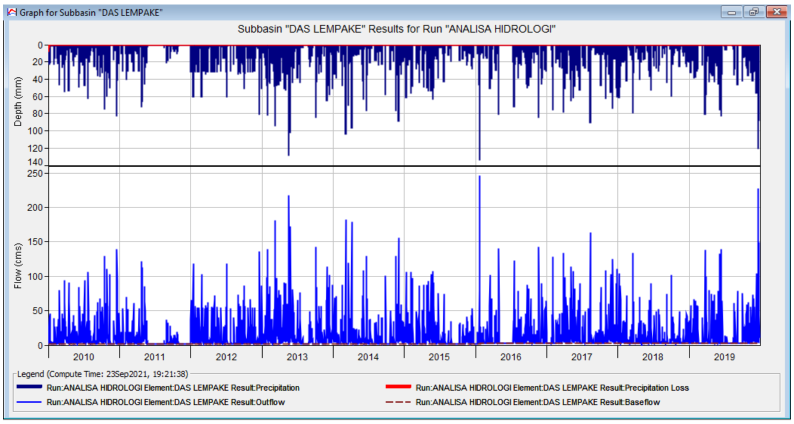

Figure 6: graph of modeling results for 10 years after calibration

Based on the analysis of the HEC-HMS method, the peak discharge from the simulation model after calibration is 446.7 m3/s and the total outflow volume is 23259.95 mm with the peak discharge time occurring on January 21, 2016. The availability of water which is defined as the mainstay discharge is discharge that is always available with a reliability of 90% where the probability is calculated by the following equation:

Pr = m / (n+1) * 100 %

With :

Pr = probability (%)

M = data number

n = number of data

The results of the recapitulation of the mainstay discharge analysis as the inflow discharge of the Lempake Dam are presented in Table 5.3 and Table 5.4. Furthermore, for the calculation of water balance simulation planning to determine the benefits of weirs in serving raw water needs, the MOCK method is used.

Table 5: Percentage of Mainstay Debit Determination 90% Based on FJ. Mock Basic Year Lempake Dam watershed

No.	Year	Discharge (m^3/s)		P (%)	Year
1	2000	18.68	25.98	4.76	2008
2	2001	18.76	23.30	9.52	2004
3	2002	13.83	19.62	14.29	2013
4	2003	11.26	19.34	19.05	2005
5	2004	23.30	18.76	23.81	2001
6	2005	19.34	18.68	28.57	2000
7	2006	14.54	17.74	33.33	2007
8	2007	17.74	16.91	38.10	2017
9	2008	25.98	16.08	42.86	2009
10	2009	16.08	16.06	47.62	2019
11	2010	14.87	15.57	52.38	2012
12	2011	7.62	15.45	57.14	2014
13	2012	15.57	14.87	61.90	2010
14	2013	19.62	14.54	66.67	2006
15	2014	15.45	13.83	71.43	2002
16	2015	13.04	13.23	76.19	2016
17	2016	13.23	13.04	80.95	2015
18	2017	16.91	11.26	85.71	2003
19	2018	11.23	11.23	90.48	2018
20	2019	16.06	7.62	95.24	2011

Mainstay discharge analysis is the minimum discharge used to determine the amount of discharge in the river or used as an analysis of water availability, so that it can be seen whether the discharge is able to meet the required water needs. The mainstay discharge analysis method uses the Fj Mock method, where this method assumes that some of the rain that falls will be lost as evapotranspiration, some will immediately become direct run off and some will enter the soil (infiltration). This method is based on monthly rainfall data. The curvature of reservoir capacity is a graph of the relationship between elevation, area, and storage volume. This calculation is based on a contour map with a height difference of 1 meter each. From the calculation of the curvature of the reservoir capacity, the normal water level is obtained at an elevation of ±7.20 m.

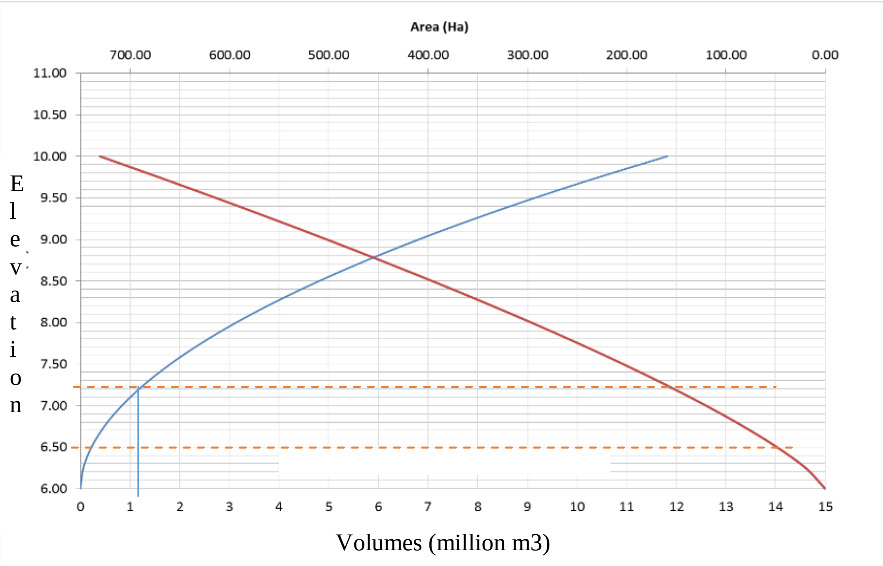

Figure 7: relationship between elevation, area and volume of inundation

Stability analysis using Plaxis 2D software application version 20 required soil parameter data from laboratory data such as d, , c. To find soil parameter values that are not obtained from laboratory results, you can use empirical formulas or correlation tables. The earthquake parameters were taken based on the Earthquake Zoning Map referring to the PusGen Indonesia Earthquake Map (2017) with a return period of 100 years having an earthquake load value of 0.00 – 0.05 g, while for a 10,000 year return period the earthquake load value was 0.10 – 0. ,15 g.

Table 6: Data of plaxis . input soil parameters

Zona	γ unsat	γ sat	Permeability mm/day	c	phi	E	v
	kN/m3	kn/m3		kn/m2	°	kn/m2	
Soil -1	17,50	17,50	0,30	14,00	22	5500	0,30
Soil – 2	18,50	18,50	0,30	5,00	18	5000	0,30
Dam	16,80	16,80	0,30	12,00	20	6000	0,30
Random Fill	18,50	18,50		10,00	21	6500	0,30

Lempake Dam will be analyzed when the water level is normal, when the water level is flooded and earthquake, and conditions are fast receding (Rapid Drawdown). So that the number of safety on the dam is known.

1. Geometry of the soil

The steps in plaxis are soil geometry, input material according to soil data, then modeling is carried out as below.

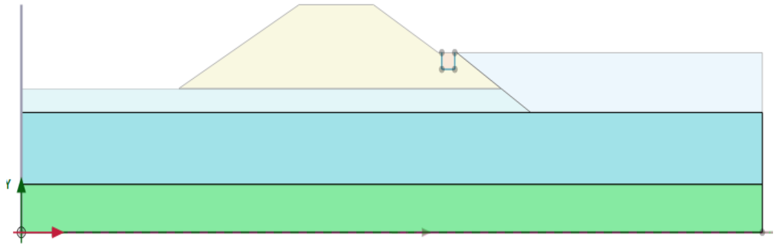

Figure 7: lempake dam geometry

2. Generate Mesh

At the generate mesh stage, the analysis network model on the dam body design will be known. Based on the analysis of the generated mesh, the network model in the modeling is a triangle.

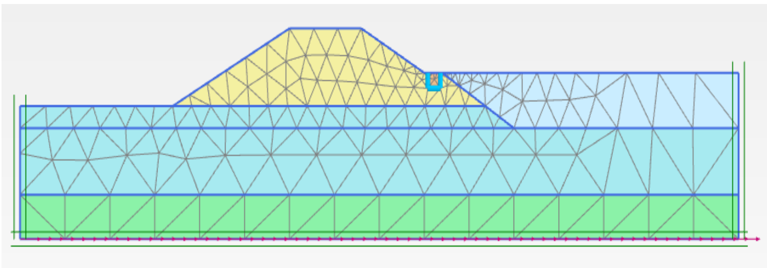

Figure 8: generate mesh of lempake dam

3. Output Plaxis 2D

The next stage in Plaxis is flow conditions, namely determining the water level to be analyzed by entering flood water level data, normal water levels and assumptions during rapid events. After the water level has been input, then at the staged construction stage, determine the point for stability analysis in the reservoir. Then start the analysis by calculating. The following is the geometry of the water table to be analyzed.

a) Normal water level

The condition in which the reservoir reservoir is filled with water to the top of the lighthouse

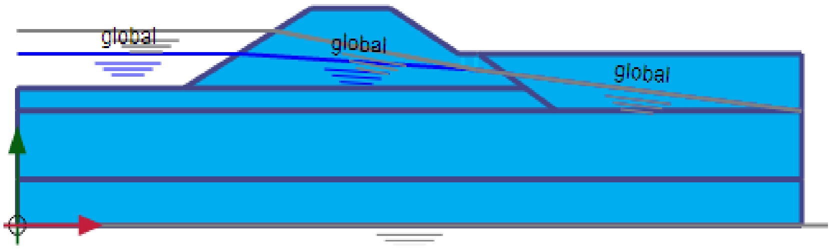

Figure 9: geometry of the dam water level when the water level is normal

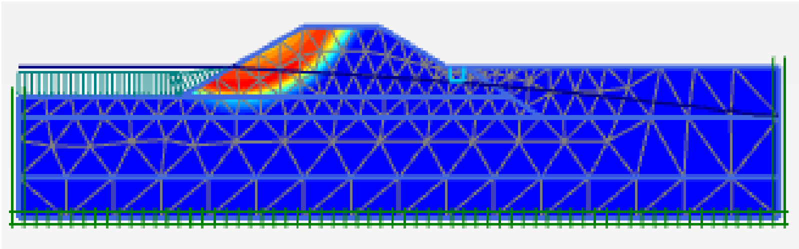

Figure 10: model of dam landslide when normal water level SF = 3.414

b) Flood and earthquake water levels

The condition where the water in the reservoir overflows above the crest of the dam accompanied by an earthquake acceleration load. The earthquake acceleration load uses time history with an earthquake a = 0.05g as shown in Figure 11.

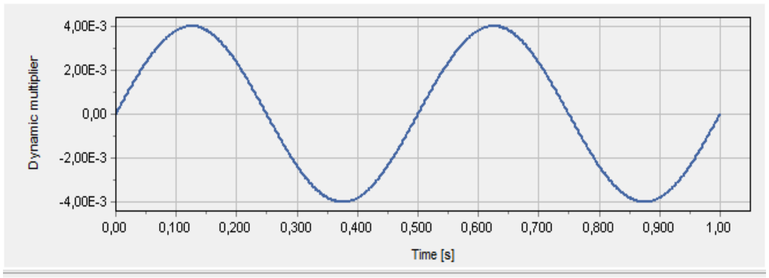

Figure 11: time history is equivalent to a = 0.355g

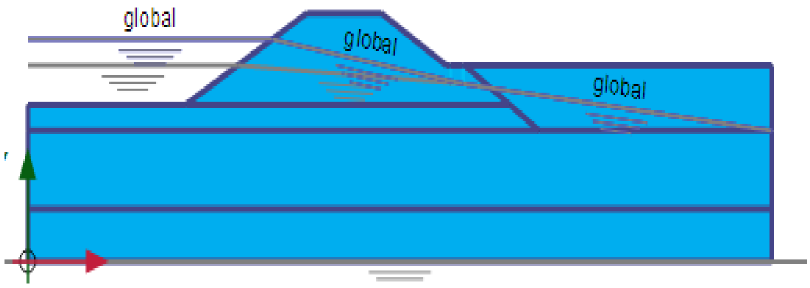

Figure 12: water level geometry of the dam during floods and earthquakes

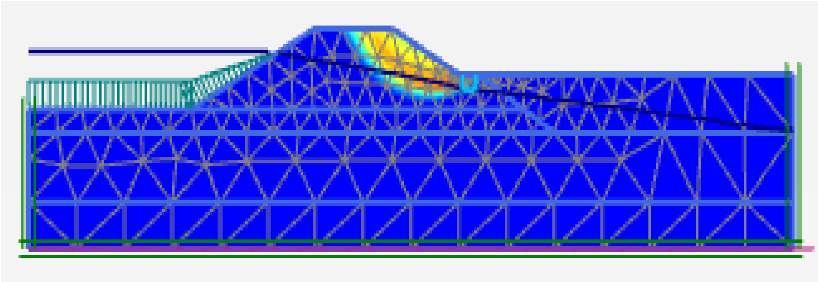

Figure 13: model of dam landslide during flood and earthquake SF = 2,984

c) Rapid Drawdown Condition

A condition where the water level is above the flood water level and suddenly recedes quickly to normal water level.

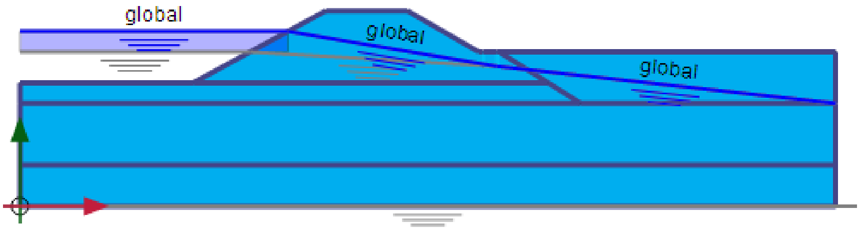

Figure 14: geometry of dam water level during Rapid Drawdown

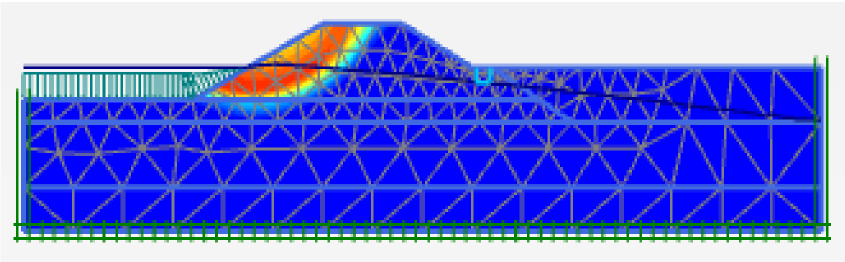

Figure 15: model of dam landslide during rapid drawdown SF = 2.819

V. CONCLUSION

Based on the results of the studies that have been carried out, the following conclusions are obtained:

1. From the calculation of the design flood discharge analysis with a return period (R1000) of 580.09 m3/second,
2. Based on the calculation of the effective capacity of 0.43 x 106 m3. While the total amount of water that can be accommodated by the Lempake Dam is 1597730,2 m3 at an elevation of +7.20 m, so that all available water can be used to meet irrigation needs, raw water and flood control.
3. The results of the stability analysis of the Lempake Dam using Plaxis 2D software Version 20 are quite safe. When the normal water level is SF = 3,414, when the flood water level and earthquake is SF = 2,984 and during the rapid drawdown SF = 2,819.
4. Suggestions after calculating and analyzing the stability of the embankment type dam, it is necessary to analyze seepage or underground erosion which also affects stability, further research is needed on strengthening or improving the soil under the reservoir and stability can be done using applications other than Plaxis 2D version 20 as a comparison.

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