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Dam Seepage Control Uses the Blanket Layer Method

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Abstrak. Analisis rembesan yang terjadi pada bendungan perlu dilakukan untuk menentukan apakah besarnya aman untuk mencegah keruntuhan pada tubuh bendungan. Metode blanket layer atau selimut kedap air merupakan metode yang digunakan dalam pengendalian rembesan. Penelitian ini membahas efektifitas metode blanket layer dalam mengurangi besar rembesan yang terjadi pada tubuh bendungan dengan meninjau besar rembesan dan stabilitas terhadap gaya angkat atau uplift. Studi kasus pada Bendungan Telagasari Kota Balikpapan yang mengalami kehilangan air akibat adanya bocoran atau rembesan pada jalur pelimpah dilakukan dengan melakukan beberapa skenario pada analisis. Berdasarkan hasil pemodelan penambahan lapisan blanket hulu menghasilkan penurunan debit rembesan yang terjadi terhadap kondisi sebelum adanya pengendalian rembesan sebesar 98,97%.

Kata Kunci: bendungan; bendali; selimut kedap air; rembesan dan gaya angkat.

Abstract*. An analysis of the seepage occurring on the dam needs to be done to determine whether the size is safe to prevent collapse on the dam body. The blanket layer is a method used in seepage control. This study discussed the effectiveness of the blanket layer method in significantly reducing the seepage on the dam body by reviewing the significant drainage and stability against the uplift. A case study of Telagasari Flood Control Dam (Bendali), which suffered a water loss due to leakage on the sewer path, was carried out by performing several scenarios of analysis based on the modelling of the addition of the blanket layer, which resulted in a 98.97% decrease in the drain discharge that occurred against the conditions prior to the drain control.*

Keywords: *dam; flood control; blanket layer methods; seepage control and uplift.*

INTRODUCTION

Seepage occurs in the dam and is not a problem. However, seepage can be a significant problem if the material of the dam body is carried. Water spills onto the slope can decrease the soil's vital sliding parameters, causing a slide (Apriani, Mustofa and Hidayat, 2020). The seepage must be overcome to prevent damage to the dam structure (Gopal and Kiran, 2014). Assessment of the stability of a slope, both natural slopes and artificial slopes such as dams, is an attempt to analyze how safe these slopes are against avalanche hazards (Apriani, Mustofa and Azhary, 2021). The erosion (piping) can generate a speed that causes erosion because it develops from the centre of the excretion with a relatively significant difference in the height of the pressure (Directorate of Engineering Affairs, 1999). The probability of dam failure occurring at a construction age of fewer than five years is 50%, and 25% is due to drainage factors (Candra and m. donny, 2008). Water saturation in the slopes due to the blockage of the filter on the toe drain can cause collapse so that there is a slight erosion of the material in the toe drain, resulting in the slope's surface becoming relatively steep and water-saturated, causing total collapse. In addition, the collapse of the body and foundation of the dam can also be caused by errors in the dam's planning and implementation of construction (Ministry Of Public Works, 2005). Predicting the collapse of the drainage and handling the drainage can reduce the risk of collapse. Treatment of drainage is done on the body of the dam and the foundation of the dam. One of Indonesia's most frequently used drainage controls is the blanket layer method. The blanket layer is a waterproof blanket that serves to lower the drainage gradient with a waterproof slate layer on the top of the dam and connects with a waterproof layer (core) (National Standardization Agency, 2016).

The Telagasari Flood Control Dam (Bendali) in Balikpapan City serves as a building to store excess water when it rains and release it when the season is dry. On May 17, 2021, the Telagasari Dam's water dried up quickly. Besides, it is suspected that the sheet pile is released and hangs underneath the spillway. The research focuses on using the blanket layer method to reduce the seepage on the dam and the safety factor against the uplift. Based on the modelling of the scenario it carried out, namely on the conditions of existence with the sheet pile off, the conditions of the addition of the blanket layer in the hood of the reservoir, the addition of the sheet pile in the hood of the reservoir, and the conditions of the combination between the addition of the blanket layer in the hood of the reservoir and the installation of the sheet pile in the hood of the reservoir, so we can find out the best methods of handling the discharge.

METHODS

The pore water pressure causes a high lifting force that causes an uplift, upheaval, or blowup usually occurs when a foundation layer with a high permeability coefficient is beneath the dam's body. The high permeability will trigger a collapse when the lifting pressure below the unconfined foundation layer can increase the output gradient (National Standardization Agency, 2016). Safety factors against high lifting pressure are considered by Equation 1 (Ministry Of Public Works, 2017):

$$FK = \frac{\gamma_n}{\gamma_w \times h} = \frac{G_s \times t}{(1+e)h} > 2 \quad (1)$$

With n being the volume weight of foundation material (t/m3), t is the total head (m), and h is the pressure head (m).

The effectiveness of the seepage control method in this study was done using several modelling scenarios to analyze the exhaust discharge and the safety factor (fk) against the uplift. The modelling scenario is divided into four:

a. Scenario I: Existing with presumed sheet pile released
b. Scenario II: With the addition of a blanket layer upstream of the reservoir
c. Scenario III: With the addition of sheet pile upstream of the spillway
d. Scenario IV: A combination of adding a blanket layer upstream of the reservoir and adding a sheet pile upstream of the spillway.

The entire scenario was analyzed with the help program of Geostudio with SEEP/W (Directorate General of Highways, 2012). A case study of this study is the Telagasari Dam which has elements such as a reservoir, spillway, drainage door and energy damper. Technically, the dams are flood control dams with the elevation of the top of the dams + 22,50 meters, the breadth of the dams + 20,00 meters and the location of the dams can be seen in Figure 1.

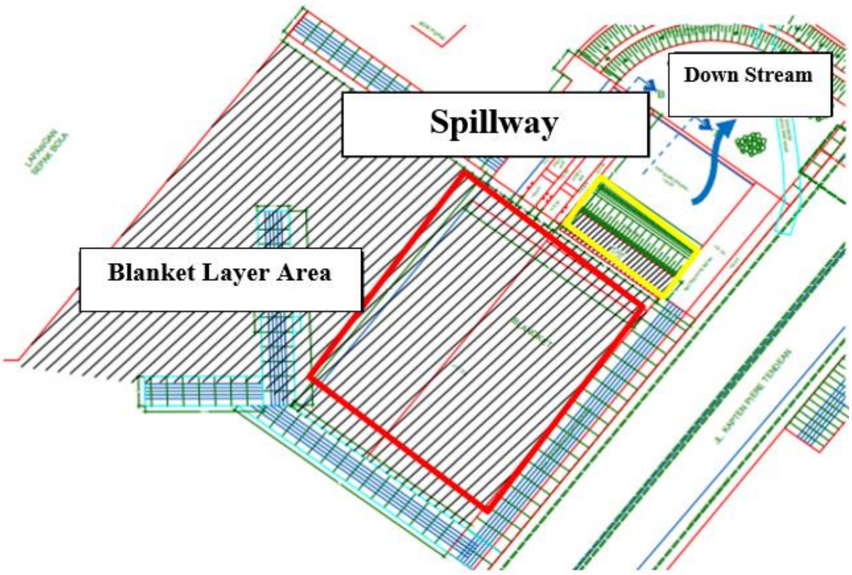

Figure 1. bendali telagasari area

Source: Wahyudi (2021)

The layer under the Bendali foundation is divided into three main layers: The first layer dominates the upper layer, which results from sedimentation in the reservoir water capture area and contains much organic material. Second layer: Dominate layers up to a depth of 15–18 m below the mud layer with a permeability coefficient (k) between 10^{-3} and 10^{-4} cm/s. This K value is sufficiently porous to allow water to flow vertically or horizontally. Third layer: waterproof layer under the sand layer of 18 to 20 meters. The material permeability values are relatively small, between 10^{-5} and 10^{-6} cm/dt or even smaller. The drainage values will be influenced by the surface conditions of the flood that occur based on the conditions of the drainage field. The elevation of the Bendali Telagasari flood face is based on the calculation of the flood tracking through the spillway of 20,43 meters.

RESULT

Seepage analysis for scenario one on Geostudio SEEP/W software is an existing condition with a leaked pile sheet. The analysis is done in a steady state on existing conditions or before applying the blanket layer method using ground data on the spillway area. The simulation results in Figure 2 show the pattern of the flow of the excretion that occurs, the flow line, and the gap between the sheet pile that also exists through the space of the end of the pile sheet with the waterproof layer. On the clay layer, there is no visible flow line due to the small permeability value of slate, and it is a waterproof layer while the colour difference occurs in the ground contours caused by the water pore pressure, that is, the pressure caused through the fluid flow that is in the pores of rocks or soil. Then the discharge flow that occurs in scenario one under existing conditions obtained a value of 1 x 10^{-3} m^3/ sec by converting the debit value per second into daily discharges and then obtains the value of 86,4 m^3/day while the capacity of the reservoir volume based on the elevation of the surface of the water is estimated at 38.779 m^3 which means the discharge which occurs exceeds the volume of the deposits of the Bendali Telagasari, can be predicted according to the results of the investigation that there are leakages that occur under the foundation of the spillway. Based on the acceptance criteria values of the drain that occurred for the height of the dam of 20 – 40 meters, the draining value is safe if less than 3,5 x 10^{-4} m^3/sec and not safe if greater than 7 x 10^{-4} m^3/sec (Look, 2007). In modelling scenario 1, a seepage discharge value of 1 x 10^{-3} m^3/sec > 7 x 10^{-4} m^3/sec is obtained, so the modelling condition of scenario 1 is unsafe, so it requires seepage control methods to mitigate the drain.

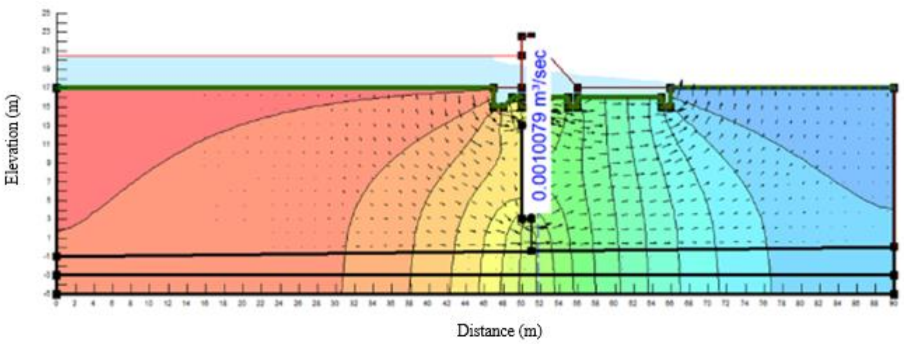

Figure 2. Seepage simulation in scenario 1

Source: Analysis (2023)

Seepage analysis in scenario two involves adding the blanket layer upstream of the reservoir with the missing sheet of the pile, as in Figure 3. With the addition of a waterproof layer with an area of +2500 m^2 and a depth of 1 m, the modelling results showed that the discharge occurred less because the front part has been given a waterproof layer in the form of a slide that reduces the discharge. The permeability value of this waterproof layer is based on laboratory test data of k = 7,14 x 10^{-8} according to the technical characteristics of the dam based on Nakasato (Sosrodarsono and Takeda, 1977). Then the drain discharge in scenario 2 obtained a value of 1,0259 x 10^{-5} m^3/sec and experienced an initial decrease of 1 x 10^{-3} m^3/sec. Based on the results of modelling scenarios 1 and 2, the addition of blankets of waterproof material caused the water drain that flowed under the foundation to decrease. In modelling scenario 2, with the addition of the blanket layer, a seepage discharge value of 1,0259 x 10^{-5} < 3,5 x 10^{-4} m^3/sec was obtained. The modelling condition of scenario 2 is safe from the excess drain.

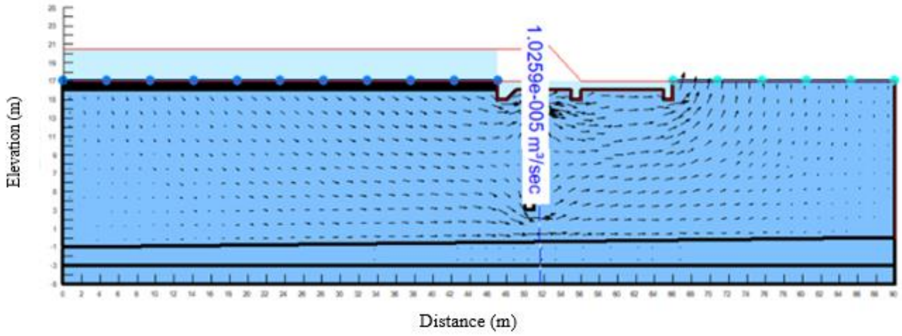

Figure 3. Seepage simulation in scenario 2

Source: Analysis (2023)

Seepage analysis for scenario 3 is based on adding the sheet pile at the head of the pile, according to Figure 4. The scenario 3 condition is an analysis to determine how much influence sheet piles have on decreasing the discharge because the construction has sheet piles underneath the spillway. Based on the results of the simulation obtained, the seepage discharge value of 8 x 10^{-4} m^3/sec suffered a decrease, which initially 1 x 10^{-3} m^3/sec but not as much as the decline that occurred in modelling scenario 2, so in addition to posing a potential hazard in terms of the installation method, the result of the analysis of the decreased discharges is not as great in scenario 2. In modelling scenario 3, with the addition of a pile sheet in the pile header, the seepage discharge value is 8 x 10^{-4} m^3/sec > 7 x 10^{-4} m^3/sec. If the difference between the existing condition and the added condition of a sheet pile in the upstream spillway is 0,0001 m^3/sec, then the modelling condition in scenario 3 is not safe from the excretion that occurs, so there is a need for the control method of exhaustion.

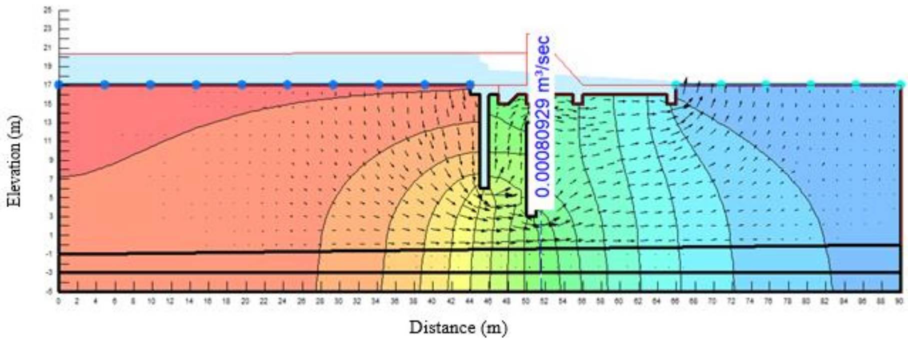

Figure 4. Seepage simulation in scenario 3

Source: Analysis (2023)

Seepage analysis for scenario 4 is a combined condition between adding a blanket layer upstream of the reservoir and adding a sheet pile upstream of the spillway, as shown in Figure 5. This scenario four models applies the addition of a waterproof layer with a thickness of 1 meter. The permeability value of the waterproof layer is based on laboratory data of k = 7,14 x 10^{-8}. Then the drain output in scenario 4 of 9,89 x 10^{-6} m^3/sec decreases, initially 1 x 10^{-3} m^3/sec. This modelling scenario decreases the amount of drain compared to scenario 2. It is an influence of the addition of sheet piles in the spillway. If reviewed from the standpoint of the decrease in drainage discharge, scenario 4 is more effective than scenario 2, but this scenario is challenging to implement on existing dams because the implementation of the sheet pile can interfere with the stability and safety of the dams. In modelling scenario 4, with the addition of a blanket layer and a sheet pile in the spillway head, this resulted in the occurrence of a seepage discharge value of 9,89 x 10^{-6} < 3,5 x 10^{-4} m^3/sec, much smaller than the acceptance criteria for drain (Look, 2007), so in modelling scenario 4, there was no excess drain.

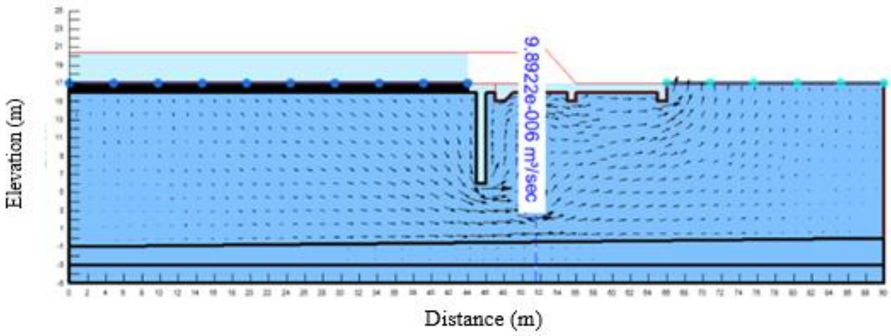

Figure 5. Seepage simulation in scenario 4

Source: Analysis (2023)

The uplift pressure analysis is based on the seepage analysis at SEEP/W, so for the uplift value in scenario 1, according to the overview point in Figure 6, the values of t and h (water total head and water pressure head) are 18,99, whereas h is 4,93. So:

$$FK = \frac{Gs \ x \ t}{(1+e)\ h} > 2$$

(Ministry Of Public Works, 2017)

$$FK = \frac{2,6648 \ x \ 18,99}{(1+1,24)\ 4,93} > 2$$

$FK = 4,58 > 2$ (OK)

Then for the analysis of the uplift pressure in modelling scenario one, it is safe, meaning that the uplift pressure on the previous layer beneath the spillway is not large enough to transfer the percentage of the current water pressure to the lateral part so that no collapse occurs.

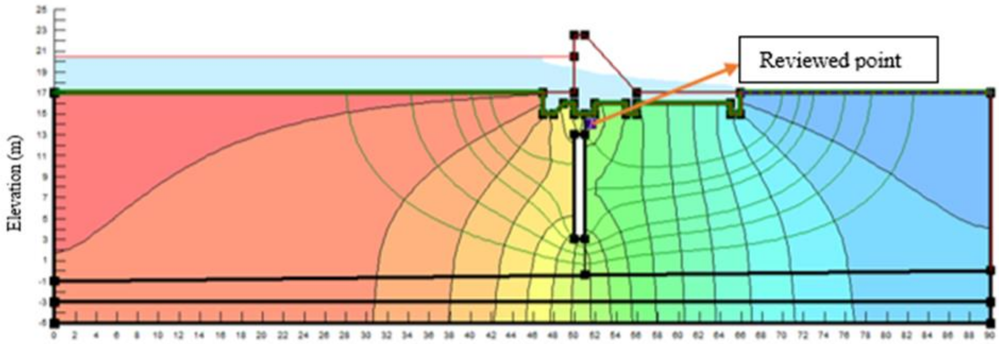

Figure 6. Uplift point review for scenario 1

Source: Analysis (2023)

In scenario two, the values of t and h (water total head and water pressure head) at the corresponding point of Figure 7 are t = 17,01 and h = 2,96. So:

$$FK = \frac{Gs \ x \ t}{(1+e)\ h} > 2$$

$$FK = \frac{2,6648 \ x \ 17,01}{(1+1,24)\ 2,96} > 2$$

$FK = 6,84 > 2$ (OK)

Then the analysis of the uplift pressure on modelling scenario 2 included safe, which means the uplift pressure on the previous layer underneath the reservoir base is not large enough to transfer the percentage of the current water pressure to the sliding part so that no collapse occurs.

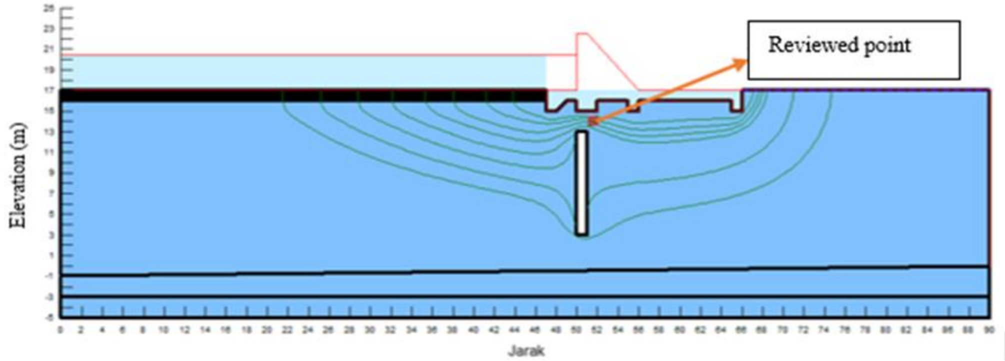

Figure 7. Uplift point review for scenario 2

Source: Analysis (2023)

The uplift pressure analysis is based on the seepage analysis at SEEP/W, so for the uplift value at scenario 3 in Figure 8, the t and h values (water total head and water pressure head) are t = 18,24 and h = 4,19. So:

$$FK = \frac{Gs\ x\ t}{(1+e)\ h} > 2$$
$$FK = \frac{2{,}6648\ x\ 18{,}24}{(1+1{,}24)\ 4{,}19} > 2$$
$$FK = 5{,}17 > 2 \text{ (OK)}$$

Then the analysis of the uplift pressure on modelling scenario 3 included "safe," which means the uplift pressure on the previous layer underneath the base of the slurry is not large enough to transfer the percentage of the water pressure to the sliding part, so there is no collapse.

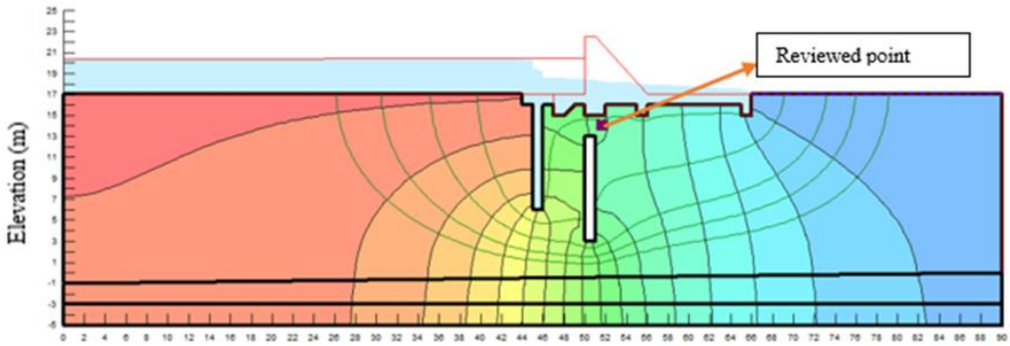

Figure 8. Uplift point review for scenario 3

Source: Analysis (2023)

The uplift pressure analysis is based on the seepage analysis at SEEP/W, and for the uplift value at scenario four, according to Figure 9, the t and h values (water total head and water pressure head) are obtained: t = 17,01, whereas h = 2,96, so that:

$$FK = \frac{Gs\ x\ t}{(1+e)\ h} > 2$$
$$FK = \frac{2{,}6648\ x\ 17{,}015}{(1+1{,}24)\ 2{,}96} > 2$$
$$FK = 6{,}83 > 2 \text{ (OK)}$$

Then the analysis of the uplift pressure on modelling scenario 4 included "safe," which means the uplift pressure on the previous layer beneath the base of the slurry is not large enough to transfer the percentage of the water pressure to the sliding part, so there is no collapse.

DISCUSSION

The percentage of reduction in seepage discharge and uplift safety for all scenarios can be seen in Table 1. Based on the recapitulation of the results of all analyses, it can be concluded that all modelling scenarios can reduce the seepage discharge that occurs. The modelling scenario with the most significant percentage is in the combined condition of adding the Blanket layer method and sheet pile up to 99,011%. When viewed from the point of view of the installation method, sheet piles can pose a potential hazard to dam stability because their installation creates vibrations so that the decrease in seepage discharge that occurs using sheet piles is more suitable to be applied during planning at the beginning while looking at the percentage of decline, the difference is only 0,041% with a note that all modelling scenarios are safe from high uplift pressure. Hence, the effectiveness of the best modelling scenario is scenario 2 with the addition of a blanket layer upstream of the reservoir.

Prevention due to uplift is carried out by calculating the safety factor with Equation 1. Based on the results of calculations with this equation, the safety score for the uplift must be more than 2, while the safety score for all analysis results is worth more than 4 so that it is declared safe. The best safety score is in the analysis with scenario 2, and this occurs because the area of the impermeable area given makes the water flow distance longer than the method in the other scenarios. Meanwhile, in scenario 1 it produces a small safety value against uplift because the distance of the water flow is only limited by the sheet pile on the spillway. The safety figures for uplift in each analysis are in Table 1.

Table 1. Effectiveness Analysis of Seepage Control Methods

Mean Water Level (20.43 m)				
	Scenario 1	**Scenario 2**	**Scenario 3**	**Scenario 4**
Seepage discharge (m^3/sec)	1×10^{-3}	$1{,}026 \times 10^{-5}$	8×10^{-4}	$9{,}89 \times 10^{-6}$
Control	Not OK	OK	Not OK	OK
Uplift Safety Factor (>2)	4,58	6,84	5,17	6,83
Control	OK	OK	OK	OK
Percentage of Scenario I	0	Lower up to 98,97%	Lower up to 20%	Lower up to 99,011%
Control	-	Effective	Effective	Effective

Source: Analysis (2023)

CONCLUSION

Using a blanket layer for seepage control can reduce the seepage discharge by 99.011% in scenario 4 with a combined condition of adding a blanket layer upstream and adding a sheet pile upstream of the spillway. However, this scenario requires an analysis of the stability of the existing dam related to its implementation in the field. In the Telagasari Bendali condition, scenario two can reduce the discharge by 98.97% from the initial condition and is safe against the uplift that occurs, namely (6,84 > 2).

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