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The Effect of Using an Impermeable Blanket on the Uplift pressure Under Concrete Dams

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ABSTRACT

In this research paper, we have studied the effect of using an impermeable blanket and compare it with the usage of cutoffs on the uplift pressure under concrete dams. This comparison has been conducted numerically, by using the element method, with the help of the Groundwater Modeling System software program. The length of the impermeable blanket has been modified according to length of the dam base, for different values of length of cutoffs. It has been found that the existence an impermeable blanket with two cutoffs doesn't lead to decreasing the uplift pressure force in comparison with the state of the non-existence of an impermeable blanket. Also, it has been concluded that using an impermeable blanket with one single cutoff at the beginning of the dam leads to decreasing the uplift pressure force by 17% in comparison with the state of the non-existence of an impermeable blanket, if the length of blanket is larger than the depth of the front cutoff.

KEYWORDS: Seepage, Concrete dam, uplift pressure, Cutoffs.

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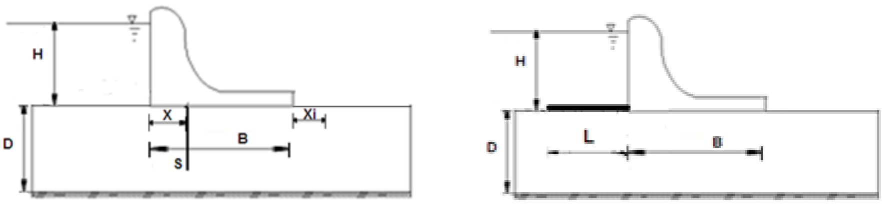
1. Introduction

Water facilities are among the most important facilities used to better invest water resources. Therefore, studying the problems that hinder their design constitutes the basic principle in their maintenance and stability. These water facilities such as (dams, regulators, and weirs) are implemented either on permeable or impermeable foundations, and as a result of the difference in water levels between the upper and lower reservoirs, water seeps through the soil, causing serious problems that may directly affect the balance and stability of these facilities [1,3,5,6,7].

As we know, the leakage rate under concrete dams is reduced by extending the flow line of the leaking water using cutoffs (one or several cutoffs), or by creating a tight blanket (cartilage) in front of the facility, as shown in Figure (1). There are many methods for studying the seepage under concrete dams and determining the water lift forces. They can be classified as numerical methods (finite element method - finite difference method), experimental methods (resistance factor method - Blay and Lin approximate method - pressure line prism method - network drawing method), laboratory methods (sand box model, viscous flow model, electrical similarity model), Mathematicall methods (Schwarz Christoffel transform method, Fourier series method) [1,2,4,6].



(A) USE OF CUTOFF *(B) USE OF AN IMPERMEABLE BLANKET*

FIGURE (1) METHODS OF EXTENDING THE LEAKING CURRENT LIN

Many researchers have studied the problem of seepage under concrete dams and have provided solutions to this problem using various methods. An overview of the most important research studies in this field.

- Rizgar Ahmed Karim (1988) studied the effect of the presence of two cutoffs of different lengths on the lifting pressure and hydraulic gradient behind water structures, relying on the finite element method [6].
- Wesam Sameer Mohammed-Ali (2011) presented a study on the effect of using a cutoff located in the middle of the base of the water facility (the case of having two cutoffs at the beginning and end of the facility) on the leakage under the water facility. The study proved that the pressure of the lifting forces decreases the closer the front cutoff is to the lower chamber and its length is equal to the length of the rear cutoff. The lifting pressure forces also decrease with the increase in the length of the cutoff [8].
- Nassir (1993) used the finite element method to analyze the seepage beneath water structures to obtain the pressure distribution beneath their base and the hydraulic gradient changes behind the structure along the lower reaches [9].

2. Research aim

This research aims to study the effect of using a leak-impermeable blanket on the water lift forces and their moments, and to compare it with the case of using front cutoff, back cutoff or two cutoffs together, in the case of the presence of water in the upper chamber of the dam only, i.e., in the worst investment case for dams (the case of no flow in the lower chamber corresponding to a water height equal to zero), as shown in Figure (2).

3. Methodology

In this research, the effect of using an impermeable blanket in front of the dam was studied using the GMS (Groundwater Modeling System) computer program within the Seep/2D environment, which is based on the Finite Element Method. The following points were discussed through the study:

1− Studying the effect of using an impermeable blanket on the water lift forces, for different depths of the impermeable layer.

2− Studying the effect of using an impermeable blanket with a front cutoff, for different lengths of the front cutoff.

3− Studying the effect of using an impermeable blanket with a back cutoff, for different lengths of the back cutoff.

4− Studying the effect of using a blanket with two front and back cutoffs.

5− Comparing the use of the blanket only with the use of cutoffs.

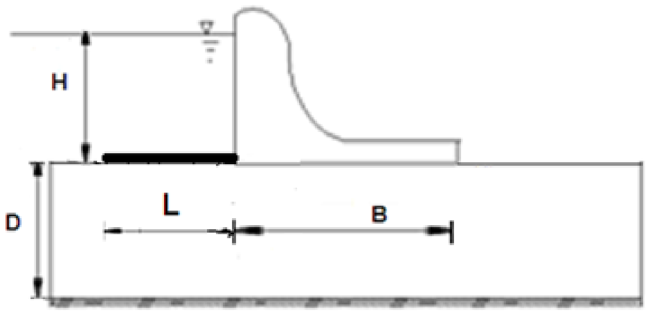


FIGURE (2) BLANKETHEBLANKETICAL MODEL

4. Verification of the computer program (GMS)

There are many methods for calculating the lifting pressure forces under concrete dams, including:

1- Blay's method: This method depends on the distribution of lifting pressures in a vertical manner proportional to the length of the best flow line, which consists of the dam base contact line and the contact lines of the anti-seepage cutoffs. This method depends on a coefficient related to the type of foundation soil on which the dam rests and is inferred through field observation of existing facilities in which no collapses of the soil of the channel behind the facility occurred[1].

2- Resistance factors method (Chugaev method): This method depends on determining the resistance coefficients for the horizontal elements, vertical elements, and the inlet and outlet of the seepage line [1].
3- Numerical modeling method: This method depends on the finite elements method to study the flow under water facilities, using the GMS program to determine the water lifting forces under concrete dams, by drawing the flow network consisting of isobaric lines and flow lines, as in Figure (3).

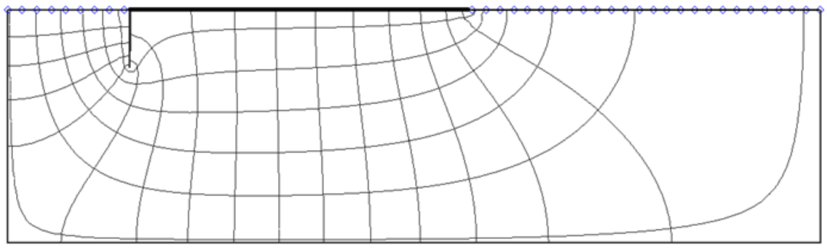


FIGURE (3) THE FLOW NETWORK UNDER THE CONCRETE DAM USING GMS

In this research, the work of the used program was verified by comparing the results derived from the program with the results calculated by the Blay method and the resistance factors method. Figure (4) shows the effect of the relative length of the blanket on the relative lifting forces under the dam for , by applying the Blay method and the resistance factors and the numerical method using GMS, where stands for the water height in front of the dam, stands for the depth of the impermeable layer, stands for the width of the dam base, stands for the water lifting force with the presence of the blanket, and stands for the water lifting force without the presence of the blanket. We note from Figure (4) that the maximum difference between the results derived from the program and the results calculated by the Blay method is equal to 4%, while it is equal to 14% compared to the results calculated by the resistance factors method. The difference between the results can be explained by the assumptions proposed by each method, which allows the application of this program to study the seepage under concrete dams.

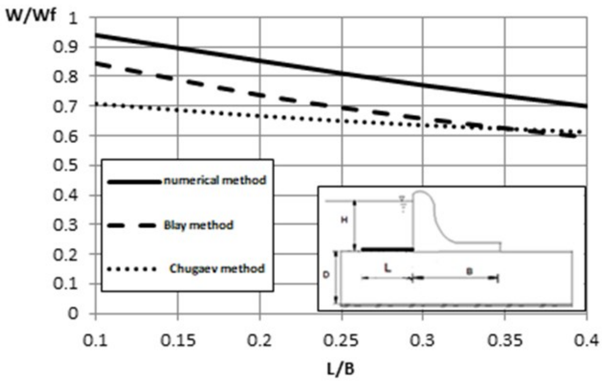


FIGURE (4): THE EFFECT OF THE RELATIVE LENGTH OF THE BLANKET ON THE RELATIVE LIFTING PRESSURE FORCE USING (BLAY METHOD - CHUGAEV METHOD - NUMERICAL METHOD)

5. Results and discussion

5.1. The effect of the presence of an impermeable blanket in front of the concrete dam

Figure (5) shows the effect of the relative length of the front blanket $\left(\frac{L}{B}\right)$ on the relative uplift force $\left(\frac{W}{W_f}\right)$ under concrete dams, depending on different relative depths of the impermeable layer $\left(\frac{D}{B}=1,2,3\right)$. W stands for the uplift force in the presence of a cutoff, W_f stands for the uplift force in the absence of a cutoff, L stands for the length of the blanket, and B stands for the width of the dam base. We note from Figure (6) that the value of the uplift force decreases significantly in the presence of the blanket compared to its absence. Also, increasing the length of the blanket reduces the value of the uplift forces, as doubling the length of the blanket leads to a decrease in the value of the uplift force by [7%], while tripling the length of the blanket leads to an increase in the uplift force by [17%].

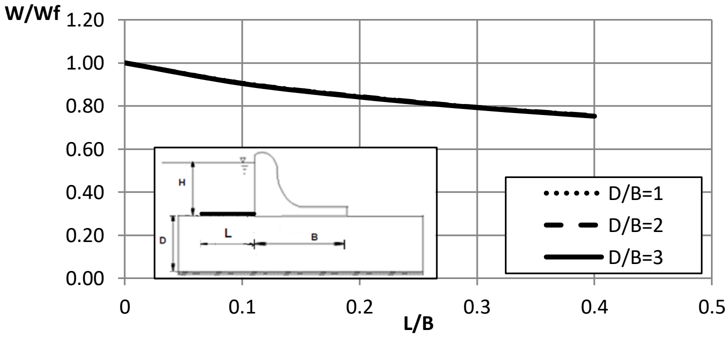


FIGURE (5) THE EFFECT OF THE LENGTH OF THE BLANKET ON THE LIFTING FORCES UNDER THE CONCRETE DAM

relative uplift moment $\left(\frac{M}{M_f}\right)$ under concrete dams, depending on different relative depths of the impermeable layer $\left(\frac{D}{B}=1,2,3\right)$. M stands for the uplift moment in the case of a blanket, M_f stands for the uplift moment in the case of no blanket, L stands for the length of the blanket, and B stands for the width of the dam base. We note from Figure (7) that the value of the uplift moment decreases significantly with increasing the length of the blanket, as doubling the length of the blanket leads to a decrease in the value of the uplift moment by [7%], while tripling the length of the blanket leads to a decrease in the uplift moment by [27%].

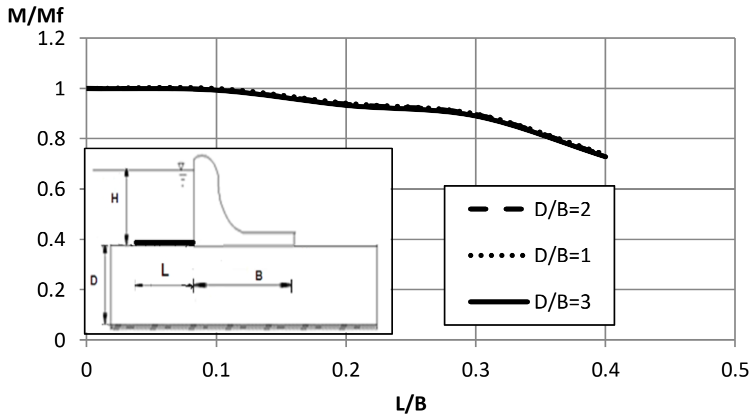


FIGURE (6) THE EFFECT OF THE LENGTH OF THE BLANKET ON THE MOMENTS OF THE LIFTING FORCES UNDER THE CONCRETE DAMS

5.2.The effect of the presence of a blanket and a front cutoff

Figures (7) and (8) show the effect of the relative length of the blanket $\left(\frac{L}{B}\right)$ on the relative uplift pressure force and its moment $\left(\frac{W}{W_f}\right)$, $\left(\frac{M}{M_f}\right)$ under concrete dams, according to different relative lengths of the front cutoff $\left(\frac{S}{B}=0.1, 0.3, 0.5\right)$ and for $\left(\frac{D}{B}=1, \frac{X}{B}=0.05\right)$. Where W is the uplift pressure force in the presence of a cutoff, W_f is the uplift pressure force in the absence of seals, L is the length of the blanket, S is the length of the cutoff, X is the distance of the cutoff from the beginning of the dam, and B is the width of the dam base. We note from Figure (8) that the value of the lifting pressure force decreases more significantly in the case of the presence of a blanket and a cutoff together than in the case of the absence of leakage barriers. Also, increasing the length of the blanket reduces the value of the lifting pressure significantly when the length of the front cutoff is $\left(\frac{S}{B}\leq 0.3\right)$. Beyond this value, the effect of the length of the blanket is small, as doubling the length of the blanket leads to a decrease in the value of the lifting pressure force by 7%, while tripling the length of the blanket leads to a decrease in the value of the lifting pressure force by [17%], when the length of the front cutoff is $\left(\frac{S}{B}\leq 0.3\right)$. While when the length of the front cutoff is $\left(\frac{S}{B} > 0.3\right)$, doubling the length of the blanket leads to a decrease in the value of the lifting pressure force by 1%, while tripling the length of the blanket leads to a decrease in the value of the lifting pressure force by 8%.

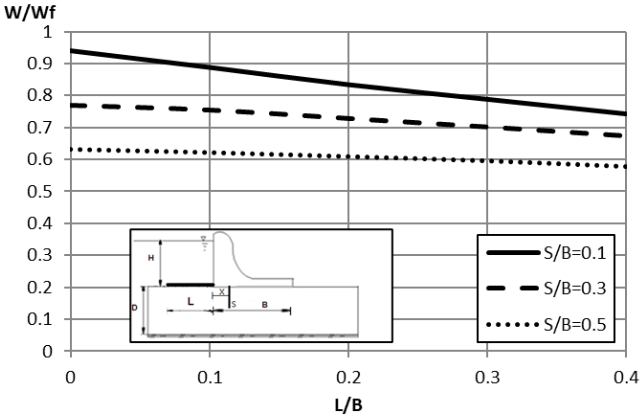


FIGURE (7) THE EFFECT OF THE LENGTH OF THE BLANKET ON THE LIFTING FORCES UNDER CONCRETE DAMS IN THE PRESENCE OF A FRONT CUTOFF.

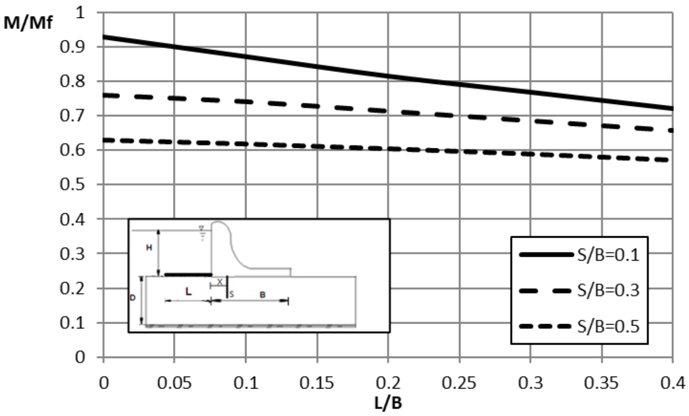


FIGURE (8) THE EFFECT OF THE LENGTH OF THE BLANKET ON THE MOMENTS OF THE LIFTING FORCES UNDER THE CONCRETE DAMS IN THE CASE OF THE PRESENCE OF A FRONT CUTOFF.

5.3. Economic comparison between using the front cutoff and using the blanket

Figures (9) and (10) show the effect of the relative length of the blanket $\left(\frac{L}{B}\right)$ on the relative uplift force and its moment $\left(\frac{W}{W_1}\right), \left(\frac{M}{M_1}\right)$ under concrete dams, according to different relative lengths of the front cutoff $\left(\frac{S}{B}=0.1,0.3,0.5\right)$ and for $\left(\frac{D}{B}=1,\frac{X}{B}=0.05\right)$. Where W is the uplift force in the case of a blanket with a cutoff, W1 is the uplift force in the case of a front cutoff only, M is the uplift force moment in the case of a blanket with a cutoff, M1 is the uplift force in the case of a front cutoff only. The values of the uplift forces and moments resulting from the use of the blanket were attributed to the values of the uplift forces and moments in the case of the use of a cutoff only as a comparison between the effect of the blanket length and the effect of the front cutoff length on the uplift force forces. It is noted from the figure that the presence of the blanket has a clear effect in reducing the lifting forces when its length exceeds the length of the front cutoff, as we find that when the length of the blanket is four times the length of the cutoff $\left(\frac{L}{S}=4\right)$, the value of the lifting pressure force is $\left(\frac{W}{W_1}=0.789\right)$; while when the length of the blanket is 80% of the length of the cutoff $\left(\frac{L}{S}=0.8\right)$, the value of the lifting pressure force is $\left(\frac{W}{W_1}=0.915\right)$. Thus, the presence of the blanket increases the cost if its length is smaller than, or equal to, the length of the front cutoff.

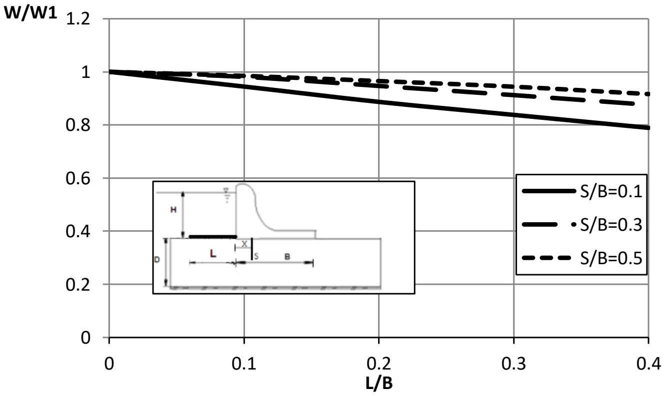


FIGURE (9) COMPARISON BETWEEN THE EFFECT OF USING THE BLANKET AND USING THE FRONT CUTOFF ON THE LIFTING FORCES UNDER CONCRETE DAMS

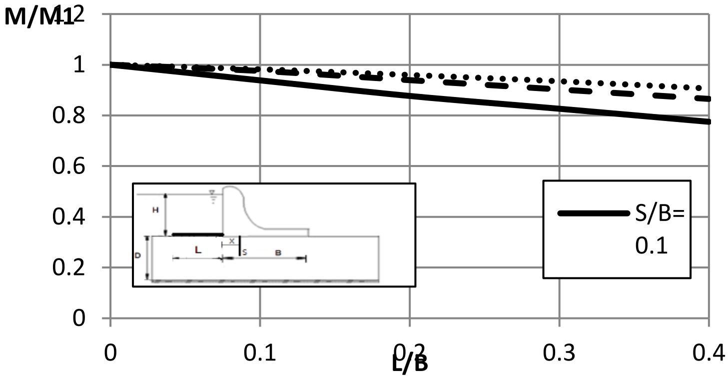


FIGURE (10) COMPARISON BETWEEN THE EFFECT OF USING THE BLANKET AND USING THE FRONT CUTOFF ON THE LIFTING FORCE MOMENTS UNDER CONCRETE DAMS

5.4.Effect of having a blanket with a back cutoff

Figures (11) and (12) show the effect of the relative blanket length $\left(\frac{L}{B}\right)$ on the relative uplift pressure force and its moment $\left(\frac{W}{W_f}\right),\left(\frac{M}{M_f}\right)$ under concrete dams, according to different relative lengths of the back cutoff $\left(\frac{S}{B}=0.1,0.3,0.5\right)$ and for $\left(\frac{D}{B}=1\right)$. We notice from Figure (12) that the value of the uplift pressure force decreases significantly with increasing blanket length, as doubling the length of the blanket leads to a decrease in the value of the uplift pressure force by [10%], while tripling the length of the blanket leads to a decrease in the uplift pressure force by [16%], but increasing the length of the back cutoff leads to a significant increase in the uplift force.

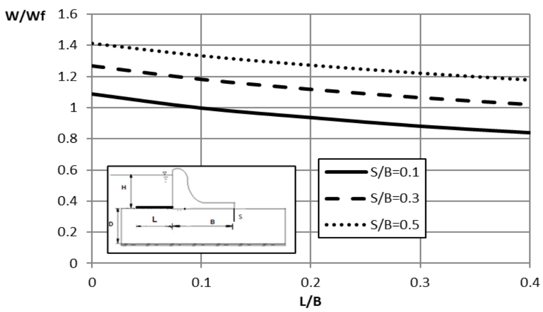


FIGURE (11) THE EFFECT OF THE LENGTH OF THE BLANKET ON THE LIFTING FORCES UNDER CONCRETE DAMS IN THE PRESENCE OF A BACK CUTOFF

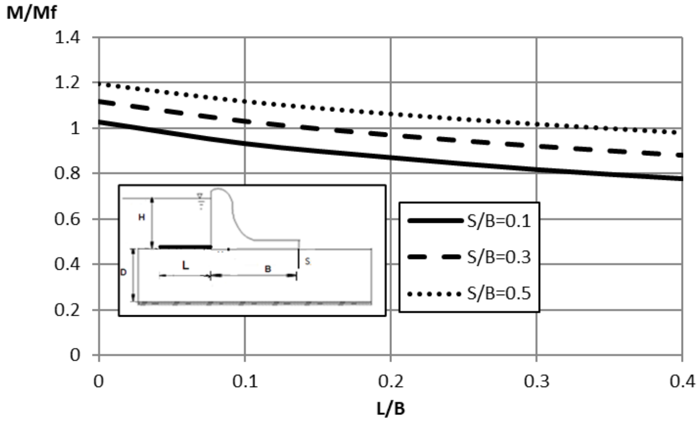


FIGURE (12) THE EFFECT OF THE LENGTH OF THE BLANKET ON THE MOMENTS OF THE LIFTING FORCES UNDER THE CONCRETE DAMS IN THE EVENT OF THE PRESENCE OF A BACK CUTOFF.

5.5. Economic comparison between using the back cutoff and using the blanket

It is noted from Figure (13) that the presence of the blanket has a clear effect in reducing the lifting forces when its length exceeds the length of the back cutoff, as we find that when the length of the blanket is four times the length of the back cutoff $\left(\frac{L}{S}=4\right)$, the value of the lifting pressure force is $\left(\frac{W}{W_1}=0.773\right)$; while when the length of the blanket is 80% of the length of the back cutoff $\left(\frac{L}{S}=0.8\right)$, the value of the lifting pressure force is $\left(\frac{W}{W_1}=0.833\right)$. Thus, the presence of the blanket increases the cost if its length is smaller than or equal to the length of the back cutoff.

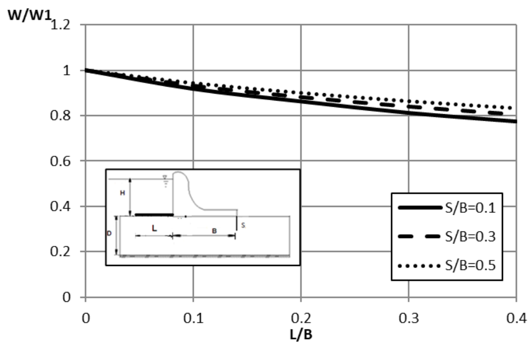


FIGURE (13) COMPARISON BETWEEN THE EFFECT OF USING THE BLANKET AND USING THE BACK CUTOFF ON THE LIFTING FORCES UNDER CONCRETE DAMS .

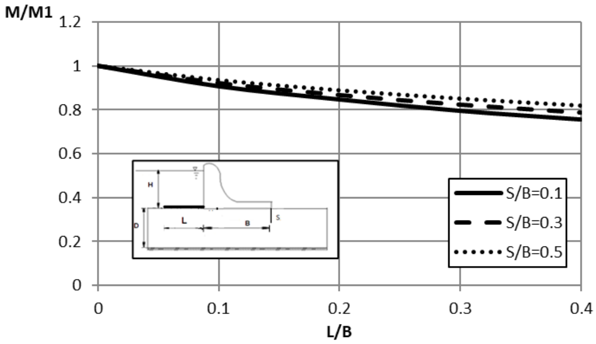


FIGURE (14) COMPARISON BETWEEN THE EFFECT OF USING THE BLANKET AND USING THE BACK CUTOFF ON THE LIFTING FORCE MOMENTS UNDER CONCRETE DAMS

5.6. Studying the presence of a blanket with two front and back cutoffs

Figure (15) and (16) show the effect of the relative blanket length $\left(\frac{L}{B}\right)$ on the relative uplift pressure force and its moment $\left(\frac{W}{W_f}\right),\left(\frac{M}{M_f}\right)$ under concrete dams in the presence of two front and back cutoffs, according to different ratios of the lengths of the two cutoffs $\left(\frac{S_1}{S_2}=0.5,1,2\right)$ and for $\left(\frac{D}{B}=1,\ \frac{H}{B}=0.3\right)$. We note from Figure (15) that the value of the uplift pressure force decreases by a very small percentage with increasing the length of the front blanket in the presence of two cutoffs. Doubling the length of the blanket leads to a decrease in the value of the uplift pressure force by [3%], while tripling the length of the blanket leads to a decrease in the uplift pressure force by [11%], but increasing the length of the rear cutoff leads to a significant increase in the uplift force.

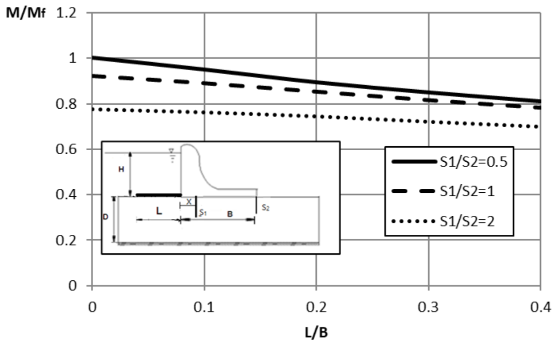


FIGURE (16) THE EFFECT OF THE LENGTH OF THE BLANKET ON THE MOMENTS OF THE LIFTING FORCES UNDER THE CONCRETE DAMS IN THE CASE OF THE PRESENCE OF TWO FRONT AND BACK CUTOFFS

6. Conclusion

In this study, the effect of using an impermeable blanket on seepage beneath concrete dams was studied using a numerical method (finite element method) and the GMS program. The use of the blanket was compared with the use of a front cutoff, a rear cutoff, and two cutoffs together. The results of this study revealed the following conclusions:

1. Using an impermeable blanket in front of the dam reduces the uplift pressure and moments by 17%, and this reduction is proportional with increasing blanket length.
2. Using an impermeable blanket with a front cutoff reduces the uplift forces. The blanket plays a role in reducing the uplift forces and moments if the cutoff length is less than 30% of the dam's width. Beyond that, the blanket's effect is negligible, and its use is not cost efficient.
3. It is recommended that the blanket length be greater than the cutoff length, as its effect is negligible if its length is shorter than the cutoff length.
4. Using a blanket with a rear cutoff reduces the uplift pressure and moments by 10%.
5. When using a blanket with a back cutoff, the length of the back cutoff must be greater than the length of the rear cutoff.

6- The effect of the blanket when two cutoffs are combined is minimal, reducing lift forces by 3%

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