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Experimental investigation of parametric changes in seepage time and length into the subsoil of hydraulic structures

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Abstract
Dams and hydraulic structures are built on rivers in order to protect water resources due to global warming, to collect surface waters to provide drinking water and/or irrigation water, to prevent floods and to establish hydroelectric power plants. Dams, for example, are hydraulic structures that have more or less positive or negative environmental interactions on surface water and groundwater. One of the environmental interactions of dams and similar hydraulic structures is the seepage of accumulated water in its reservoir from upstream bottom of the dam. This seepage can affect the level and location of groundwater, reduce the accumulation of water in the reservoir, and cause piping in the ground below the construction of the dam body. In order to control the seepage, the methods of increasing the seepage length by using sheet pile and clay blanket on the dam foundation are frequently used. In this study, in the physical laboratory model, the variations in the seepage lengths that occur under the hydraulic structure section in the soil with two different grain diameters of 0.85 mm and 1.5 mm, depending on the dam structure, soil and barrier structures (sheet pile and upstream clay blanket), were experimentally investigated. As a result, it was determined that the seepage occurs less in the soil with a smaller grain diameter of 0.85 mm, the smaller the soil particle diameter has a reducing effect on the seepage, and the use of sheet pile increases this effect positively. In addition, it has been determined that the clay blanket in the upstream is effective compared to the general conditions, but the use of sheet pile provides the most efficiency.
Keywords: Clay blanket, Environmental risk, Hydraulic structure, Seepage, Sheet pile

INTRODUCTION

Hydraulic structures are engineering structures designed and built to control and use natural water resources (Sedghi-Asl et al., 2012; Mohammed-Ali, 2011). These structures must have high strength in order to provide a long and high quality service lifespan. For this reason, examining and solving the problems that the structures may encounter is a very important parameter in terms of strength and service lifespan in terms of protection of water resources from global warming adverse effects and seepage related water losses, and protection from hydraulic structure collapse (especially dams) related environmental disaster risks. Hydraulic structures built on various soils are based on the life and durability of the structure by using different methods in accordance with the structure of soil. These foundations are divided into three types as rock, coarse-grained material (sand and gravel) and fine-grained material (clay and silt) foundations. Foundation soils of hydraulic structures are mostly composed of permeable sand and gravel including relatively impermeable sections. These soils, which consist

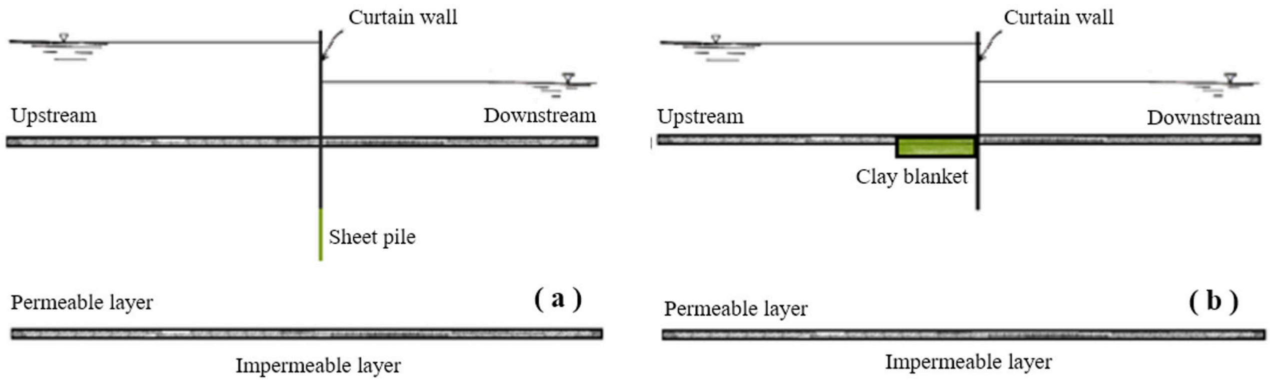

Figure 1. Schematic profile views of (a) sheet pile and (b) clay blanket examples

of material called alluvium, have a wide grain distribution range from fine sand to coarse gravel (Tosun, 2004). Having sufficient thickness of the sand and gravel layer reduces the problems in the direction of soil load transfer and structure stability to a certain level. However, the soil must be subjected to tests and analyzes due to its high permeability.

Dams, which are important hydraulic structures, together with their foundations, are structures that prevent the passage to the downstream side by creating a barrier to the water accumulating in the reservoir (Cilingir, 2007). In these structures, hydraulic load occurs as a result of the water level difference between the upstream and the downstream and seepages occur in different sections of the structure (Mohammed-Ali, 2011; Mesci, 2006). These seepages are one of the most fundamental problems affecting the stability of the structure. Seepage in the ground of structure is related to the ground medium, flow type, and limit conditions (Alghazali and Alnealy, 2015a, b, c). The seepage of water by eroding the ground causes the fine grains to be washed away and starts to be carried with larger diameter grains from the spaces formed by the movement of these grains. If this process permanently continues, the ground soil will have a porous structure. If the seepage velocity exceeds the critical value, erosion occurs on the foundation ground, which can cause dam collapse (Cilingir, 2007).

With the effect of the pressure caused by the seepage currents, the ground at the downstream boundary rises, cracks and wedge are formed in the core of the dam, and water channels are formed, creating the possibility of piping. Piping, which seriously damages the stability of the structure, is prevented by extending the seepage length by various methods (Mesci, 2006). If the amount of seepage exceeds the anticipated amount of water loss, the safety of the construction is under threat, and seepage that occurs in this context causes a swamp situation and increases the instability of the construction behavior to the maximum level (Eynur, 2004; Ullah et al., 2019). Lifting force increases in direct proportion to piping and the soil becomes more saturated with water and loses its bearing capacity (Eynur, 2004). The buoyancy force reduces the shear resistance that exists between the foundation of the structure and itself, and this situation loses the strength of the structure against overturning or sliding (Khalili Shayan and Amiri-Tokaldany, 2015). As a result of this situation, the ground of the hydraulic structure causes loss of life and property, and environmental destruction (Ullah et al., 2019). The Tigra Dam, located in India on August 4, 1917, collapsed due to seepage in the foundation and as a result of this destruction, approximately 1000 people lost their lives downstream of the dam (Ullah et al., 2019; Abay et al., 2015). The Teton Dam in the USA collapsed on June 5, 1976, for the same reason; It caused the death of 11 people and 13,000 cattle, with an estimated damage of approximately 2 billion USD (Ullah et al., 2019). It has been determined that many such collapses require a more critical and careful analysis and design of the building foundations to be built compared to other sections, and it has been stated that a problem existing in the foundation will cause the entire structure to be damaged or completely destruction (Mohammed-Ali, 2011).

Water losses due to seepage should remain within acceptable limits, if necessary, they should be removed without damaging the structure, and the related precautions should be taken into account during the design stage. The amounts and routes of possible leaks should be analyzed in detail and resolved within the framework of economical and safe conditions (Eynur, 2004). Determining the amount and route of seepage is the first step in solving the problem. Various sealing structures such as cutoff walls, source covers, downstream seepage blankets, and sheet pile trenches are used to control the resulting seepage, effectively containing water leakage at desired intervals (Figure 1.a). The low permeability layer (Figure 1.b), called the clay blanket, consists of clay material. The thickness, length, and permeability of this cover are the parameters that determine the effect of this method (Sedghi-Asl et al., 2012).

Sheet pile trenches are sealing trenches filled with cement grout or compacted clay fill, which are applied to connect the impermeable core of a hydraulic structure foundation with the impermeable layer of the foundation. These trenches are used in shallow hydraulic structures to ensure a watertight connection between the structure's body and the foundation. If the depth of the permeable layer in the structure's foundation is high, it is necessary to utilize methods such as impermeable source covers, pressure relief wells, and downstream seepage piles (Eynur, 2004). Impermeable source covers are a common practice used to increase the seepage path and prevent leakage in soils with high permeability. As the length of the seepage path increases, there is a loss of head in the water particles, leading to a decrease in their energy.

Researcher Bligh (1910), who first declared the seepage length theory, defined the seepage length as the first seepage path in contact with the foundation, and assuming that the hydraulic slope along the seepage line is constant, the energy loss along this path varies linearly with the seepage length, thus stated that the Lifting force distribution is linear (Khalili Shayan and Amiri-Tokaldany, 2015). Assumed that the total seepage length is the sum of the horizontal and vertical distances traveled by a liquid particle from the upper bed level (Sedghi-Asl et al., 2012). Based on Bligh's theory, the hydraulic slope is assumed to be constant and equal to h/L_0 anywhere along the structure, where h represents the difference between the upstream and downstream water levels, while L_0 represents the flow seepage length. It is also suggested that the seepage factor $c=L_0/h$ should be equal to or higher than an optimum value so that the structure can resist any internal erosion. According to Bligh theory, Equation 1 given below is established:

$$L=LH+LV \tag{1}$$

Where LH, horizontal leakage length; LV is the vertical leakage length. Lane (1935), who examined more than 200 damaged hydraulic structures, formed the following Equation 2, and suggested that the horizontal and vertical seepage lengths should take different coefficients:

$$L=LH/3+LV \tag{2}$$

Lane (1935) proposed the weight-seepage theory, predicting that the vertical and horizontal flow of the seepage are different and that they lose more load in the vertical direction than in the horizontal. In this theory, in order to find the total seepage length, weight coefficients of 0.33 in the horizontal direction and 1.0 in the vertical direction are assigned and if the angle of the seepage line with the horizontal is higher than 45°, it is considered vertical, and if it is lower than 45°, it is horizontal (Sedghi-Asl et al., 2012; Khalili Shayan and Amiri-Tokaldany, 2015). Sedghi-Asl et al. (2012) created a hydraulic channel model in the laboratory by using Lane and Bligh methods to ensure seepage control. The shoreline made of trapezoidal stainless steel sheet is assumed impermeable and four upstream blankets of various lengths and four sheet piles of various depths are used. As a result of the experiments, the difference between the results of the Lane and Bligh methods was quite large and it was determined that the difference between the methods decreased with the increase in the blanket lengths and the sheet pile depth. When these two methods were compared, it was observed that the results of the Bligh method were in better agreement with the experimental data, and it was presented that this was due to the different seepage lengths applied in the two methods. Based on the results, it has been determined that the Bligh method provides an accurate and economical criterion in the safety control of structures against piping, and therefore it is presented that this method would be appropriate to use for the design of hydraulic structures installed in coastal sandy soils. It has been shown that the use of both seepage control methods together is more effective in reducing the lifting force, and it has been shown that the use of larger values of the blanket length and sheet pile depth gives more appropriate results with the experimental data and determines the optimum length values. Sedghi-Asl et al. (2010) determined that the seepage volume was effectively reduced by 60%, 70%, 75%, and 82%, respectively, by applying clay blankets of various lengths (d/D=0.2, 0.4, 0.6, 0.8) at different depths. It was determined that increasing the upstream blanket length resulted in a significant reduction in the outlet hydraulic slope.

Alghazali and Alnealy (2015a, b, c) investigated the effect of sheet pile position and inclination angle (ϴ) on the uplift pressure in a physical laboratory model, based on a hydraulic structure located on a single and multi-layered soil. As a result of the study, they presented that a sheet piling inclined towards 45° upstream provides a very good efficiency by reducing the uplift pressure to 40.3%, and the seepage amount to 28.5% compared to the general situation (without sheet pile). It has also been observed that the use of a sheet pile with a slope of ϴ=120° towards the downstream is beneficial in reducing the current gradient value to 5% and increasing the safety factor against piping to 3.18. On the other hand, it has been determined that the use of sheet piles both upstream and downstream significantly reduces the amount of leakage compared to other options. Alghazali and Alnealy (2015a, b, c) concluded that a sheet pile placed at 90° angle reduces the effective uplift pressure on the ground by 45% compared to the case without sheet piling, and that a sheet pile placed at 90° towards the upstream face of the system will reduce leaks compared to a sheet pile placed at 120°. They concluded that it was 42% more efficient.

Abedi Koupaei (1991) study examined the sealing structures with different methods and under various conditions, both by laboratory and numerical methods. Koupaei stated that the amount of lifting force estimated using the theories of Bligh and Lane is less than both Khosla et al. (1936), and Finite Difference Methods (FDM). In the study of Sedghi-Asl et al. (2015), the effects of a sheet pile position on reducing seepage and flow rate under hydraulic structures were investigated by using the Finite Difference Method, and it was determined that the best position for sheet piling was upstream and downstream, respectively.

In a study by Ahmed (2011), the effects of different sheet pile configurations on buoyancy, seepage flow, and reduction of outlet slope were investigated in order to reduce leakage losses from channel beds and to design stable hydraulic structures. Consequently, it is recommended to build a clay (or very low permeability soil) core on the inner edge of the embankments. Khalili Shayan and Amiri-Tokaldany (2015) stated in their study that increasing sheet pile depth causes an increase in the leak length, a decrease in the average hydraulic slope, and thus a decrease in the amount of leakage. In this study, it was also determined that as the distance between the sheet pile and the impermeable blanket gets smaller, the increasing flow line creates a resistance and reduces the leakage, and when the sheet pile is placed at the downstream end, the leakage flow rate reaches its minimum value. In addition, in the study, it was calculated that the sheet pile placed on the upstream side affected the buoyancy force more than the upstream blanket. Khalili Shayan and Amiri-Tokaldany (2015) investigated the effects of downstream blanket and sheet pile on seepage flow, outlet slope and buoyancy reduction using a physical model created in the laboratory and two datasets obtained from GeoStudio (2007) software. Using data from these laboratory experiments, it has been observed that the best position of the sheet pile used to reduce seepage flow is at the downstream end. In addition, in the study of Khalili Shayan and Amiri-Tokaldany (2015), it has been determined that the best position of the sheet pile is the upstream side to reduce the amount of uplift pressure. The effects of sheet pile inclination on seepage flow, outlet slope, and buoyancy were evaluated using the software, and it was presented that the optimum inclination angle depends on the sheet pile position and length Khalili Shayan and Amiri-Tokaldany (2015). It was also observed in Khalili Shayan and Amiri-Tokaldany (2015) study that the effect of a sheet pile placed at the downstream end on reducing the outlet slope was greater than that of an upstream blanket. Zainal (2011) investigated the effects of the shear wall on the seepage formed in the dam foundation and concluded that the best angle to minimize the seepage flow rate, uplift pressure, and outlet slope is approximately 60°, 120° to 35° and 45° to 75°, respectively.

Ullah et al. (2019) discussed, using SEEP/W, the effect of the use of sheet pile and filter flow blankets on reducing the amount of seepage under the foundation. Ullah et al. (2019) used sheet piles, which are widely used in practice, were used under the conditions of varying depths (5m, 7.5m, and 10m) and thickness (0.5m, 1m) for leakage reduction. In the study Ullah et al. (2019), it was determined that the leakage reduction for 5 m, 7.5 m, and 10 m lengths of 0.5 m thick sheet pile decreased by 1.05%, 10.15%, and 19.75%, respectively, compared to the general situation. In sheet pile models with the same lengths and 1 m thickness, leakage improvement efficiencies were obtained as 2.29%, 12.37%, and 21.36%, respectively (Ullah, 2019). In the same study, U/S impermeable clay blankets were also used in the study to reduce the hydraulic slope and the amount of seepage in the downstream section. They modeled the 1 m thick U/S clay blanket for various lengths (50 m, 100 m, 150 m, 200 m, 250 m, and 300 m). Under the conditions where the U/S clay blanket is used (50 m, 100 m, 150 m, 200 m, 250 m, and 300 m respectively), there is a significant reduction in seepage volume compared to the dam section without control measures (55.14%, 58.65%, 59.65%, 60.44%; 60.10% and 60.14% respectively).

According to the results obtained from this study, it is possible to reduce the seepage that occurs in the foundation of hydraulic structures by taking various precautions. In addition to the seepage volume and uplift pressure examined in the studies, it is also necessary to calculate the seepage length, which should be considered in engineering calculations. In this study, unlike the literature, the seepage length parameter was investigated with two different grain diameters and application types. Seepage length, downstream transition time, and seepage path obtained by using sheet pile and upstream clay blanket related parameters were investigated with the physical model. In this way, the risk of collapse of hydraulic structures due to seepage will be eliminated and possible environmental disasters that may occur due to collapse will be prevented. In addition, since the surface waters are decreasing significantly due to global warming, the measures against the loss of water accumulated in the reservoirs by seepage into the soil in order to obtain the drinking water needed for the settlements, irrigation, and utility water needed for agriculture and livestock have been put forward in this study.

MATERIALS AND METHODS

In this study, it was aimed to examine the effect of the use of sheet pile curtains and upstream clay blankets on the amount and length of seepage in order to prevent seepage under hydraulic structures, with physical models in the laboratory in different soils (different grain diameters (d_1=0.85mm and d_2=1.5mm)). In the experiments carried out in Bursa Technical University Hydraulics Laboratory, a box-shaped apparatus made of plexiglass material with dimensions of 30x30x15cm and a thickness of 5mm was used (Figure 2). The aim of the studies is to examine the behavior of seepage lengths under hydraulic structures in different soils (different grain diameters). It has been examined how the water injected from two different points follows under normal conditions, in sheet pile condition, and in the presence of upstream blanket. The effect of the injected trace material on the seepage length of the sheet pile and upstream blanket is discussed, taking into account the transition times from upstream to downstream. In order to keep the upstream and downstream water levels determined during the experiment, a submersible water pump designed to operate in water and to prevent water leakage in the motor body was used. Soil samples with two different grain diameters were used in the experiments and the median grain sizes were determined as a result of the sieve analysis (d_1=0.85 mm and d_2=1.5 mm). A plexiglass piece with 11 cm length, 15 cm width, and 5 mm thickness representing the hydraulic structure cross-section was used in the middle of the assembly (x= 15 cm distance). In the study, 5 cm long, 15 cm wide, and 5 mm thick sheet piles and a 6 cm long and 1.5 cm thick upstream blanket were used to reduce seepage under the structure. Blue (Point B) and red (Point A) dyes were used as trace material in the experiment and the dye tracer was injected from two different designated points (A and B) of the sand-filled assembly using a 5 ml syringe (Figure 2).

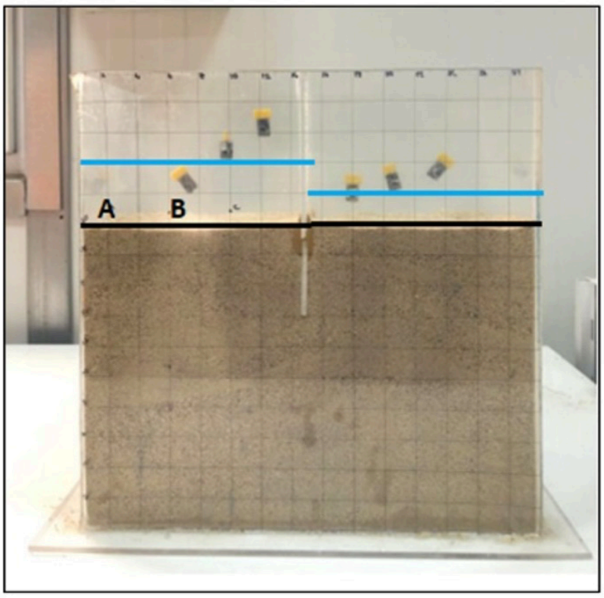

Figure 2. The experimental setup profile view

In the experiment, first of all, the ground levels determined according to the dimensions of the physical model were filled up to 20 cm in an equal way from the upstream and downstream sides. Water was added up to 24 cm on the upstream side and a submersible water pump was operated so that the water level did not exceed 22 cm at the downstream side. The reason for determining the level difference between the water levels is to create a hydraulic load, allowing seepage from the upstream side to the downstream side. After adjusting the amount of water, the trace injection points were selected. By injecting red dye from point A (2,0) where the most distant but comfortable observation can be made, and blue dye from point B, which is approximately in the middle of the upstream side, closer to the obstacle (6,0) at 30 second intervals, the progress of the trace materials is horizontal and vertical coordinate measurements were made (Figure 3). The horizontal and vertical coordinates of the seepage trajectory of the trace materials were determined depending on the time by marking the grids on the transparent front wall of the experimental setup. At the end of each test, the entire sample was emptied and washed in order to evacuate the dyes that may have remained in the ground, and the same volume of sand was placed in the apparatus to start the new test. When the tracers reached the downstream ground level, the experiments were terminated and a flow net image was obtained from the coordinates obtained on the plexiglass. In order to observe the effect of the grain diameter on the critical seepage length and the effect of the sheet pile shear and the clay blanket on the seepage length, the summary of 12 experiments is presented in Table 1.

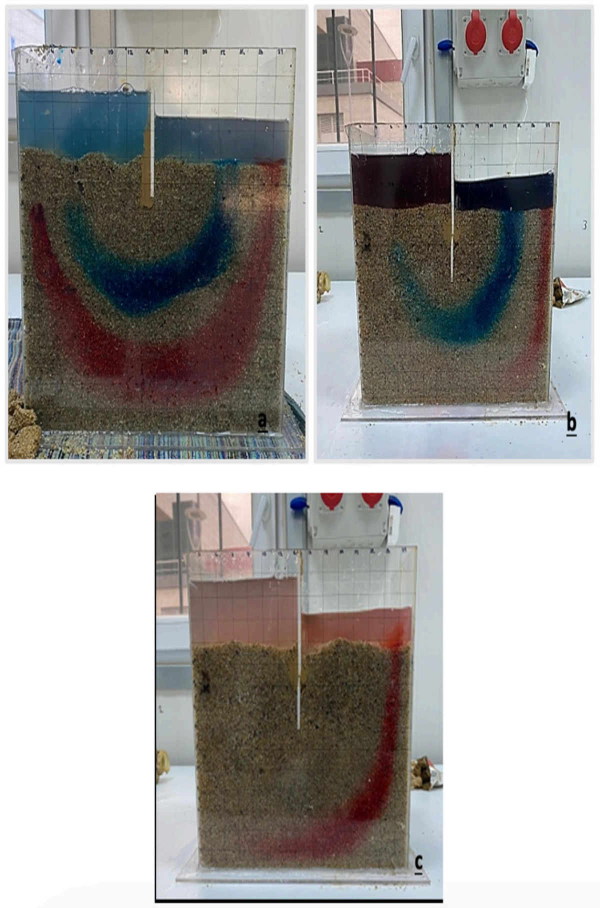

Figure 3. For identical grain diameters having experiments a) Clay blanket points A and B b) Sheet pile point B c) Sheet pile point A

Table 1. Summary of experiments

Application point	Ground 1 (d_{50}= 0.85mm)	Ground 2 (d_{50}= 1.5 mm)
Point A (2,0)	General situation Upstream blanket Sheet pile	General situation Upstream blanket Sheet pile
Point B (6,0)	General situation Upstream blanket Sheet pile	General situation Upstream blanket Sheet pile

RESULTS AND DISCUSSION

In the seepage tests performed for the same grain diameter and at the same points, it was observed that the application of clay blanket and sheet pile had the effect of increasing the seepage time and seepage length at both points ((2,0), (6,0)). In the experiment in which the sheet pile was used, it was determined that the seepage times and seepage length values increased significantly at both points when compared to the other experiments with the same grain diameter. In this study, it was calculated that the seepage length determined for the same grain diameter (d_1=0.85 mm) increased by 46.45% compared to the general situation (Table 2 (data) and Table 3 (comparison)). When the upstream clay blanket used in the experiments is compared to the general situation, it is observed that the seepage time and length increase in a high amount at the point (6,0), which is close to the dam cross-section, while the (2,0) point, which is relatively far from the dam cross-section, shows the percentage of seepage length despite the high increase in seepage time. It was observed that the increase was smaller (Table 2). The probable reason for this situation is that, as seen in Figures 4 and 5, the clay blanket placed horizontally on the upstream section is not close enough to affect the seepage trajectory of the trace material injected from the point (2,0) which is far from the dam section.

When the experiments to increase the seepage length were evaluated among themselves, it was seen that the use of sheet pile was more effective than the use of clay blanket. In the experiments carried out at (2.0) in soil with a d_1=0.85mm grain diameter, the use of sheet pile increased the seepage time by 4.5% and the seepage length by 31.4% compared to the use of upstream blanket. The percentage of seepage length increase of -1.5% in Table 3, may be due to the small

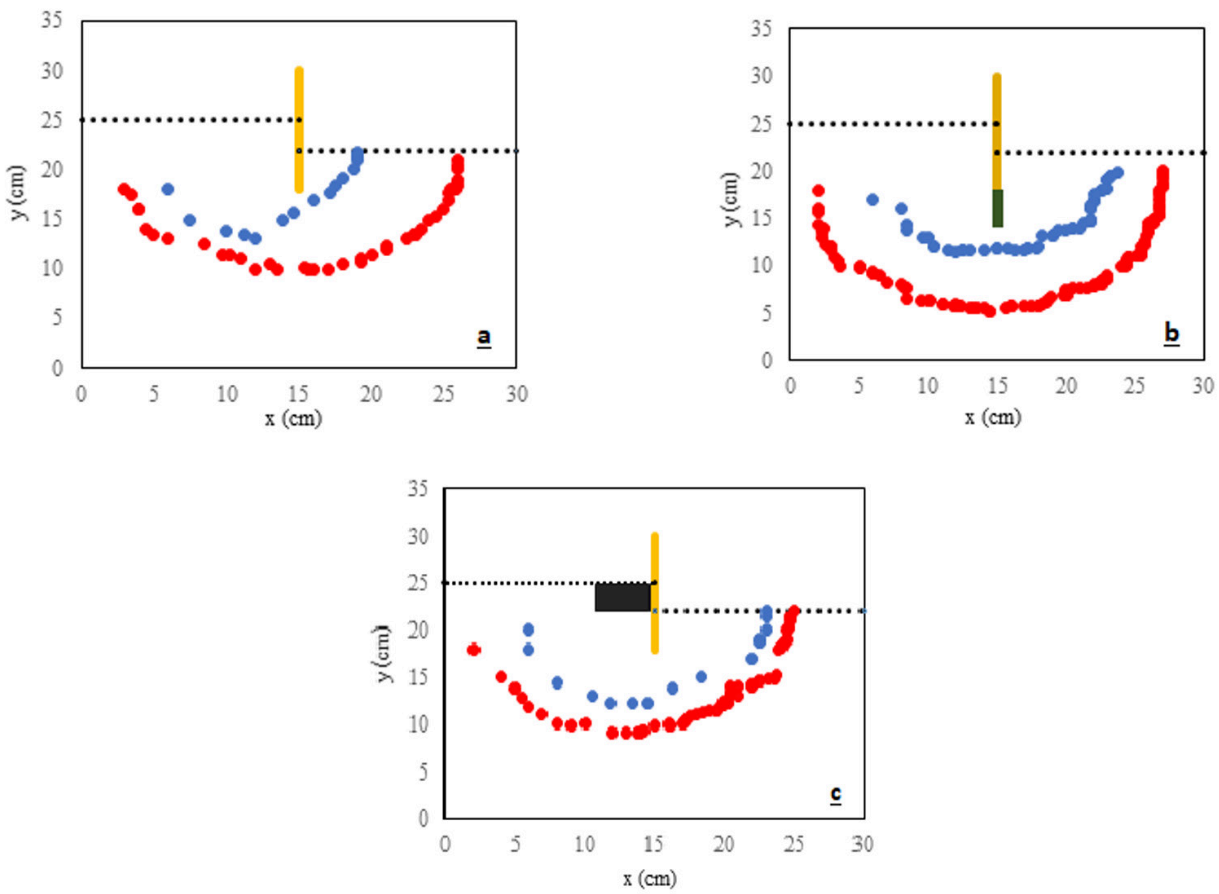

Figure 4. a) General b) Sheet pile c) Upstream clay blanket system test plots (for d_1=0.85mm)

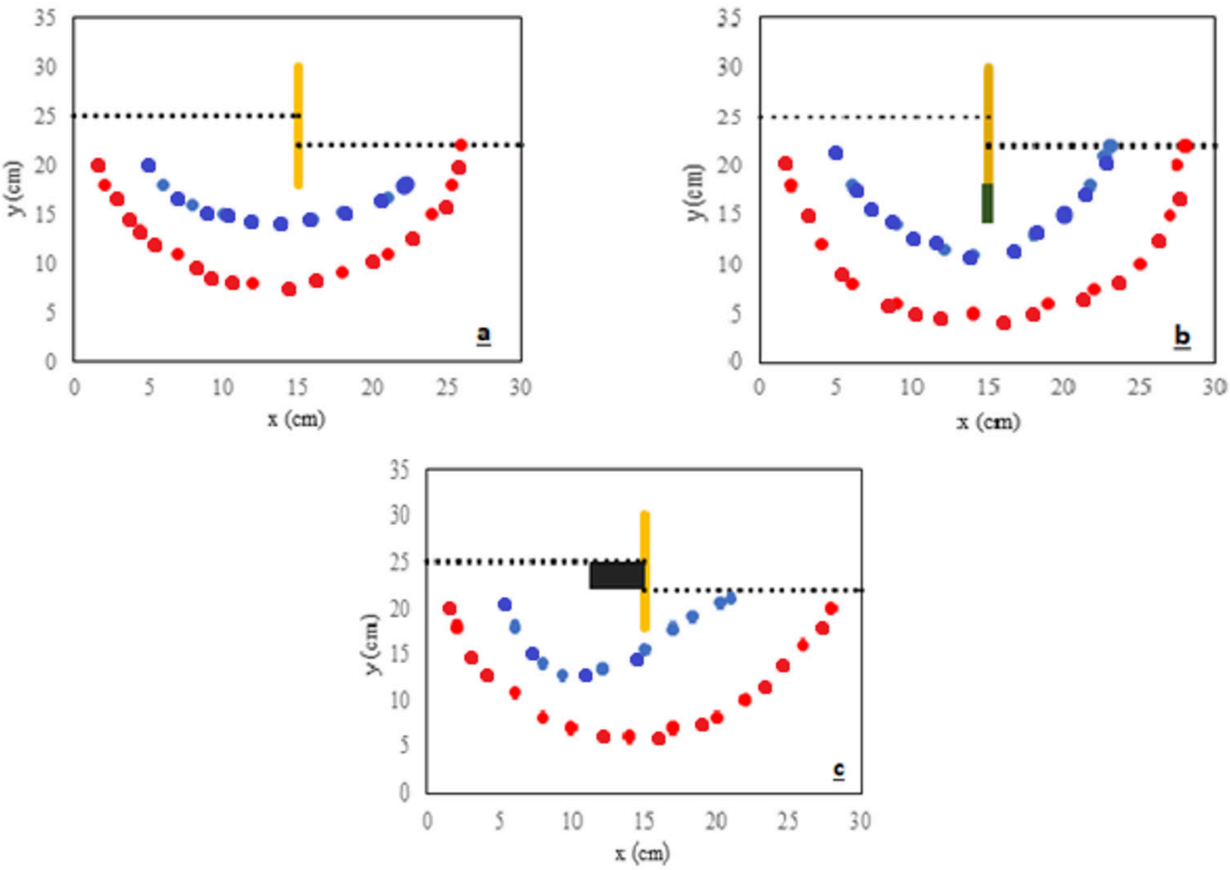

Figure 5. a) General b) Sheet pile c) Upstream clay blanket system test plots (d_2=1.5mm)

Table 2. Summary of experimental results

Grain diameter (mm)	Application point	Method	Seepage time	Seepage length (cm)
0.85	(2,0)	General situation	44min 10sec	35.31
		Upstream blanket	54min 5 sec	38.28
		Sheet pile	56min 30sec	50.30
	(6,0)	General situation	8min 12sec	19.86
		Upstream blanket	15min 57sec	27.29
		Sheet pile	25min 15sec	26.87
1.5	(2,0)	General situation	4min 3sec	36.45
		Upstream blanket	5min 3sec	38.86
		Sheet pile	5min 18sec	44.33
	(6,0)	General situation	48sec	16.76
		Upstream blanket	2min 5sec	21.08
		Sheet pile	2min 17sec	25.90

experimental deviation. In the tests carried out at (2.0) in soil with d_2=1.5mm grain diameter, the rate of seepage time was 5.0% and the seepage length was 14.1%; in the experiments performed at the point (6.0), it was observed that the seepage time increased by 9.6% and the seepage length increased by 22.9%.

When the tests performed on the same grain diameter and at different points (2,0 and 6,0) are compared, it is seen that the obstacles to increase the seepage length at the point close to the dam cross-section (6,0) are approximately 7-8 times more effective in the downstream exit time of the tracer. In the experiment with sheet pile, when compared to the general situation, the seepage time increased by 27.9% in the experiments performed at the point (2,0) on the soil with a d_1=0.85mm grain diameter, while this increase was 207.9% in the experiment performed at the point (6,0). While the seepage time increased by 30.6% in the experiments performed at (2,0) in soil with d_2=1.5mm grain diameter, the seepage time increased by 185.4% in the experiments performed at (6,0). When the experiment with a blanket is compared to the general situation, the seepage time increased by 22.5% at the point (2,0) in the soil with

Table 3. Experiment comparison table (according to the method)

Grain diameter (mm)	Main experiment	Compared experiment	Application point	Increase in seepage time to downstream (%)	Seepage length increase (%)
0.85	Sheet pile	General situation	(2,0)	27.9	42.50
	Upstream blanket	General situation	(2,0)	22.5	8.40
	Sheet pile	Upstream blanket	(2,0)	4.5	31.40
	Sheet pile	General situation	(6,0)	207.9	35.29
	Upstream blanket	General situation	(6,0)	94.5	37.40
	Sheet pile	Upstream blanket	(6,0)	58.3	-1.50
1.5	Sheet pile	General situation	(2,0)	30.6	21.60
	Upstream blanket	General situation	(2,0)	24.7	6.60
	Sheet pile	Upstream blanket	(2,0)	5.0	14.10
	Sheet pile	General situation	(6,0)	185.4	54.50
	Upstream blanket	General situation	(6,0)	160.4	25.70
	Sheet pile	Upstream blanket	(6,0)	9.6	22.90

Table 4. Experiment comparison table (according to grain diameter)

Grain diameter (mm)	Compared grain diameter (mm)	Method	Application point	Increase in seepage time to downstream (%)	Seepage length increase (%)
0.85	1.5	General situation	(2,0)	990.5	-3.10
		Upstream blanket	(2,0)	970.9	-1.50
		Sheet pile	(2,0)	966.0	13.47
		General situation	(6,0)	925.0	18.49
		Upstream blanket	(6,0)	665.6	29.45
		Sheet pile	(6,0)	1005.8	3.70

d_1=0.85mm grain diameter, while the seepage time increased by 94.5% at the point (6,0). While the seepage time increased by 24.7% in the experiments performed at (2,0) in soil with d_2=1.5mm grain diameter, the seepage time increased by 160.4% in the experiments performed at (6,0) (Table 4).

In the experiments, when the soil with d_1=0.85mm grain diameter is passed to the soil with d_2=1.5mm grain diameter, the permeability of the soil also increases, and the transition time of water from the upstream to the downstream side is greatly reduced. In the experiments performed on the same system by changing only the grain diameter, in all experiments at the point (2,0), the seepage time was 990.5%, 970.9%, 966% in the experiments at the point (6,0), it was observed that the seepage time decreased by 925%, 665.6%, and 1005.8% for the systems with general condition, upstream blanket and sheet pile, respectively (Table 4). When the seepage lengths are compared, in the experiments performed at the point (2,0), it was observed that the general situation, the system with the upstream cover and the sheet pile showed a decrease of -3.1%, -1.5% and 13.47%, respectively. Due to the relatively small dimensions of the laboratory physical scale, it is thought to cause small experimental deviations that can cause negative values. In the experiments performed at the point (6,0), the seepage time decreased by 18.49%, 29.45%, and 3.7% for the systems with the general condition, upstream blanket, and sheet pile, respectively.

CONCLUSION

Seepage is one of the main factors limiting the project lifespan of hydraulic structures and it plays a very important role in reducing seepage, protecting the collected water, and eliminating the risk of collapse of the hydraulic structure. Seepage, especially starting from under the structure, causes the risk of collapse in the structure and has the potential to cause environmental disasters, especially in dams and similar hydraulic structures. For this reason, it is necessary that the seepage length passes as far from the foundation of the structure as possible and in connection with this, the seepage length must be increased. For this reason, it is necessary that the seepage length passes as far from the foundation of the structure as possible and in connection with this, the seepage length must be increased. This subject, which was discussed in the study, was investigated on soils with different diameters by using sheet pile and clay blanket. Both the grain diameter effect and the barriers used to increase the seepage length were examined in detail and it was determined that these barriers contributed greatly to the seepage time and length. As a result of all the experiments, the experiments with obstacles placed to increase the seepage length in soil with d_2=1.5 mm grain diameter were completed in a shorter time than the general test of soil with d_1=0.85 mm grain diameter. In this case, it was concluded that the soil grain diameter was more affected by the seepage time by obstacles such as sheet pile and clay blanket. The test with the longest seepage time is the one in which the sheet pile is used on the soil with a grain diameter of d_1=0.85 mm and the dye tracer is started from the point (2,0) which is far from the dam cross section. As a result of these experimental studies, when the examined seepage prevention methods were compared, it was determined that the most effective method for reducing seepage under the dam was to reduce the grain diameter and add sheet pile under the foundation. It is also expecting from these seepage preventing arrangements that they would be helpful for maintaining lesser environmental disaster risk related to dam etc. collapse, and/or keeping more mass of water in the reservoir with lesser leak.

COMPLIANCE WITH ETHICAL STANDARDS

Conflict of interest

The authors declared that for this research article, they have no actual, potential or perceived conflict of interest.

Author contribution

The contribution of the authors to the present study is equal. All the authors read and approved the final manuscript. All the authors verify that the Text, Figures, and Tables are original and that they have not been published before.

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Ethics committee approval is not required.

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Data availability

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Not applicable.

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