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EVALUATING THE EFFECT OF SHEET PILES DEPTH ON THE SEEPAGE WATER PRESSURE USING ANYSIS PROGRAM

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Abstract

One of the primary factors that causes a hydraulic structure to fail or collapse is the issue of water seepage from beneath "concrete hydraulic structures" or via earthen hydraulic structures. Both the soil layer upon which the hydrological construction was constructed and the flood water imposed on by the difference in height upstream and downstream are potential reasons. One of the most efficient ways to prevent water seepage is to utilize concrete sheet piles underneath hydraulic concrete structures, according to earlier research. This study used the 2-d F.E. "model ANYSIS FLUENT LUNCHER 2020 R, program against water pressure and piping" phenomena in various scenarios, to assess the impact of sheet pile depth on seepage pressure. The outcomes were achieved by a drop in water pressure, which occurred while the sheet pile was located upstream and at a depth of 8 meters.

Keywords: *ANYSIS Program, Sheet Piles, Water Pressure, Water Seepage, Hydraulic Structure.*

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Introduction

The majority of dams built across the world are built on permeable soil to prevent design issues and ensure the construction's safety. The divergence in river levels between the structures' upstream and downstream components must also be taken into consideration in the design. Water leakage is one of the most significant issues that must be taken into consideration, whether it occurs through the superstructure in the case of dams or through the underlying soil in the case of concrete structures. Therefore, it's crucial to pick the appropriate rocks, pebbles, and other elements for concrete structures. The passage of liquid into soil while being subjected to a hydrostatic pressure is commonly believed to constitute seepage. The force of seepage water is represented by this hydraulic gradient, especially in relation to the soil structure. The floor explodes and the hydraulic structure fails whenever the soil depth is insufficient to support the uplift pressure [2]. There are many multiple kinds of hydraulic engineering structures, each of which serves a specific function or advantage. These structures are often used to manage water flow, measure discharge, slow down water flow, and preserve the intended water level.

As a result, the structures are built to withstand the impact of water as well as other factors such the structures' own weight, hydraulic upwelling, the stress of the current waves, etc. in addition to sustaining the dam. The causes of collapse at the bottom of hydraulic systems are the subject of one of the most significant studies, as well as one that many people believe to be the most fascinating [1]. Water seepage provides information about the porous layer's properties. The hydraulic conductivity varies within the rock formations of the soil due to its sedimentary nature, which is influenced by the transit and deposit of sediment that creates horizontal strata, and its features are not uniform in all directions.

they mount an elliptical machineThey take on an elliptical form as a result [1]. The permeability coefficient of a homogeneous soil with variable properties, where the permeability is not constant in all directions, depends on the velocity. As a consequence, the Laplace equation that follows best describes the flow:

$$kx \ \partial^2 H/(\partial x^2) + ky \ \partial^2 H/ (\partial y^2) = 0 \qquad \text{when } kx \neq ky \qquad (1\text{-}1)$$

Homogeneous soil is referred to in this situation because the characteristics of the soil are influenced by the flow's direction and the material may have consistent features with the same permeability coefficient across the flow zone. The permeability properties of this type of soil are identical to permeability properties in the xy plane according to the Laplace Equation.

$$^2\partial \ H /(\partial x^2) + \ \partial^2 H/ (\partial y^2) = 0 \qquad \text{when } kx = ky \qquad (1\text{-}2)$$

Security measures to prevent seepage are put in place, such as the installation of cutoffs, sheeting piles, filters, and wells, in order to protect the integrity of the building from failure brought on by seepage hydraulic pressure and pipelines. Concrete curtains are one of these pressure-relieving strategies [3]. In the past, trenches or mud walls have been created underground to control groundwater flow. That was a practical inexpensive technique [4].In general, a number of materials, including timber, masonry, metal, and aluminum, are used to build sheet piles [5]. The goal of the study was to ascertain, and used the Anysis program, how two scenarios affected the thickness of sheet piles and the pressure of seepage.

1.2. Control of water pressure seepage.

The cutoff, sheet piles, filters, and wells have been used to regulate the leakage of hydraulic pressure from underneath hydraulic structures and to guarantee the security of the structure from collapse as a result of the water pressure seepage and subsequent piping phenomenon, which poses a significant risk in the failure of the pumping station. These techniques to lessen pressure include concrete curtains [3]. Clay walls or ditches were historically dug underground to limit groundwater movement. That was an effective low-cost method [4]. In general, a number of materials, including timber, masonry, metal, and aluminum, are used to build sheet piles [5].

1.3. Objectives of the Study.

The following examples can help to illustrate the primary goals of this study:

1. To steadily assess, using the anysis program, the impact of sheet pile depth on seepage water pressure.
2. Determining the best line of defense against seepage water pressure and piping phenomena to safeguard hydraulic infrastructure.

2. Literature Review

Building hydraulic structures over permeable soil presents a number of challenges. The primary problem is seepage under the foundations. To stop the seepage, a number of methods were tried. As a result, a number of solutions have been created to handle the correlation of these concerns in the design and analysis of drainage systems. These solutions include experiments employing cutting-edge numerical analytical methods and computer programs.

2.1 Numerical Studies

Numerical techniques differ from analytical solutions in that they yield incredibly exact results. It stands out for its advancement in electrical computer science as well as the ease with which complex boundary conditions for issues are expressed. The finite difference technique, a type of numerical method, was one of the first methods used to investigate problems with the flow through porous media. The second method, the method of finite elements which uses mathematics to solve differential equations, is the boundary integral approach [6]. The domains of mechanical and physical applications saw the earliest implementations of this strategy. Topics related to heat transfer were discussed, and then dynamic viscosity, especially flow via porous media, was directly applied.

The method's benefits include its simplicity when the border is curved and its applicability in heterogeneous, anisotropic media. It is appropriate for locations where things change quickly because of its adaptable size and shape to fit the boundary. It is simple to compare the use of boundary conditions to the finite difference technique, which necessitates specific laws for every situation [7]. In the research that follows, seepage flow through porous media beneath hydraulic structures is modeled using these numerical methodologies. Hillo [1] investigated seepage beneath drainage systems on an anisotropic soil foundation in order to obtain the uplift stress distribution beneath the floor base and the fluctuation of exit gradients along the downstream bed. Floor height, sheet pile depth, different combinations of anisotropy degree, and stratum thickness are the parameters for which results are produced.

1 .The degree of anisotropy has no effect on the maximum exit slope at the downstream end of the device.

2 .When ($Ø< 90$), the departure slope's dispersion is less uniform in each of the scenarios examined in this work, and the discrepancy grows as the ratio (Kmax/kmin) rises.

3 -The exit gradient dispersion along the downstream bed is bigger than that for the isotropic case for all constructions based on soil stratification with an inclination angle of with horizontal axis, and the disparities get larger as (kmax/kmin).

4 -The type of constructions and the inclination angle with respect to the horizontal axis have an impact on the distribution of piezometer heads at the base of the building.

5- When hydraulic systems have a single, they respond differently in terms of piezometric head distribution. differently when hydraulic structures with a single sheet pile are built upstream than when structures with downstream sheet piles.

The typical problem of stable leakage in an impervious sheet pile wall was addressed by Al-Damluji et alsolutions to two-dimensional steady-state field issues [8]. It was discovered that a good middle ground might be found between the finite element method or shuttered solution and the boundary element approach.

Abbas [9] was able to offer an analytical solution for seepage flow beneath a dam structure with an angled cutoff that could be placed anywhere along the dam's base. The altitude and water pressure at various places were calculated using the derived equations.

The effects of the sheet pile's placement and angle downhill on uplift pressure and departure gradient were examined by Saleh and Hayder [10] using computer software (ANSYS version 11.0) and the finite element method. The most important discovery was that the ideal sheet pile angle was 1200.

In order to calculate the average rise at the pole, the exit gradient, and the amount of seepage behind cutoff walls, Imad [11] used laptop FORTRAN90. He investigated the impact of sheet pile inclination angle and position on seepage control beneath dams.

Nassralla and Rabea observed that uplift stress reduced path the floor in the event that the upstream was less than the height of the soil layer in their investigation [12] of the effects of using two layers of soil on the seepage qualities of sheet piling.By using finite element software ANSYS, Mohammed [13] examined how mutual interference stacks affected the seepage issue. Real-world results that correlated strongly with the findings were obtained. Using the pile downstream increased the uplift pressure by 11.66%, whereas using the pile upstream decreased it by 8.36%. Additionally, it was found that employing the pile upstream decreased the hydraulic structure's exit gradient by 28.28% and the rate of flow by 66.8%.

“The impacts of the cutting barrier and the vertical drainage on the flow discharge beneath embankment dams were examined by Kheiriet et al. [14]. The finite element program SEEP/W was used to model embankment dams. When the results of the embankment dam's computer modeling were constracted with those of the physical modeling”.

3. NUMERICAL MODELING.

3.1 Introduction

FLUENT LAUNCHER (2020 R2) was used to create a numerical simulation prediction to identify the

Water leakage under hydraulic installations where the following assumptions were made:

1- First off,
2- The third dimension.
3- Steady.
4- Laminar.
5- Neoclassical flow that is incompressible.

3.2 Governing Equations

The compounds of seepage velocity through the porous media according to Darcy's law are:

$$u = -k_x \frac{\partial H}{\partial x}$$

$$v = -k_y \frac{\partial H}{\partial y} \qquad (3\text{-}1)$$

$$w = -k_z \frac{\partial H}{\partial z}$$

where u, v, w represents the velocity in the directions of x, y and z, respectively.

Based on Bernoulli equation:

$$\frac{p}{\gamma\omega} + z + \frac{v^2}{2g} = H = \text{Constant} \qquad (3\text{-}2)$$

where, the flow in steady state, the velocity will be neglected and the piezometric head will be: -

$$H = \frac{P}{\gamma\omega} + z \qquad (3\text{-}3)$$

P: Hydrostatic pressure, (N/m^2), (F/L^2),

$\gamma\omega$: Unit weight of fluid, (N/m^3), (F/L^3), and

Z: Elevation head (m), (L).

The principle of fluid flow continuity through a given space produces the continuity equation of a three-dimensional flow of non-compressible fluid [**11**].

$$\frac{\partial u}{\partial x} + \frac{\partial v}{\partial y} + \frac{\partial w}{\partial z} = 0 \qquad (3\text{-}4)$$

To compensate Darcy's law (3-1) in an equation (3-4), the equation for the state of the soil becomes heterogeneous, anisotropic:

$$\frac{\partial}{\partial x}\left(k_x \frac{\partial h}{\partial x}\right) + \frac{\partial}{\partial y}\left(k_y \frac{\partial h}{\partial y}\right) + \frac{\partial}{\partial z}\left(k_z \frac{\partial h}{\partial z}\right) = 0 \qquad (3\text{-}5)$$

In the case of soil, which is homogeneous, anisotropic the Equation becomes as follows:

$$k_x\left(\frac{\partial^2 h}{\partial x^2}\right) + k_y\left(\frac{\partial^2 h}{\partial y^2}\right) + k_z\left(\frac{\partial^2 h}{\partial z^2}\right) = 0 \qquad (3\text{-}6)$$

As well as the state of homogenous soil, Equation (3-6) becomes:

$$\frac{\partial^2 h}{\partial x^2} + \frac{\partial^2 h}{\partial y^2} + \frac{\partial^2 h}{\partial z^2} = 0 \qquad (3\text{-}7)$$

This equation is known as the Laplace Equation, which is similar to the Laplace Equation in terms of velocity potential for ideal flow or the flow of non- viscosity and the state of flow in two- dimensions shorten the Equation to becomes:

$$\frac{\partial^2 h}{\partial x^2} + \frac{\partial^2 h}{\partial y^2} = 0 \qquad (3\text{-}8)$$

This Equation represents the Laplace Equation of the static laminar flow, which has different solutions [**11**].

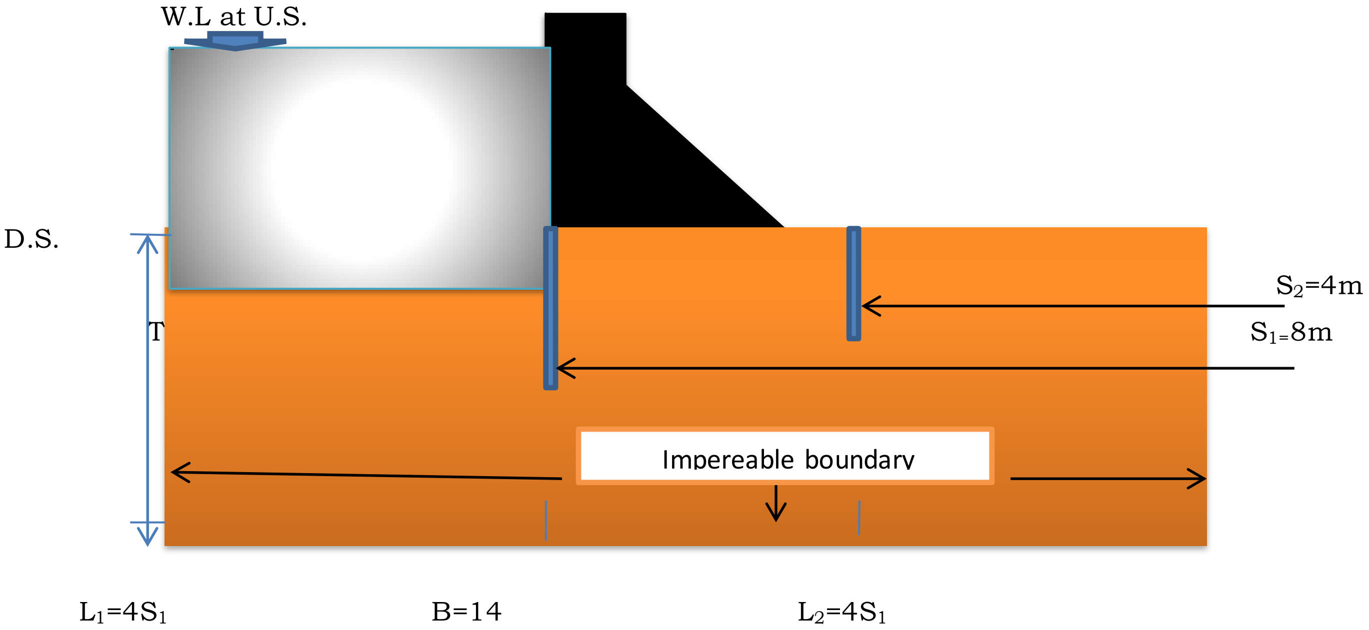


Fig.3.1: “Schematic of the considered geometry.”

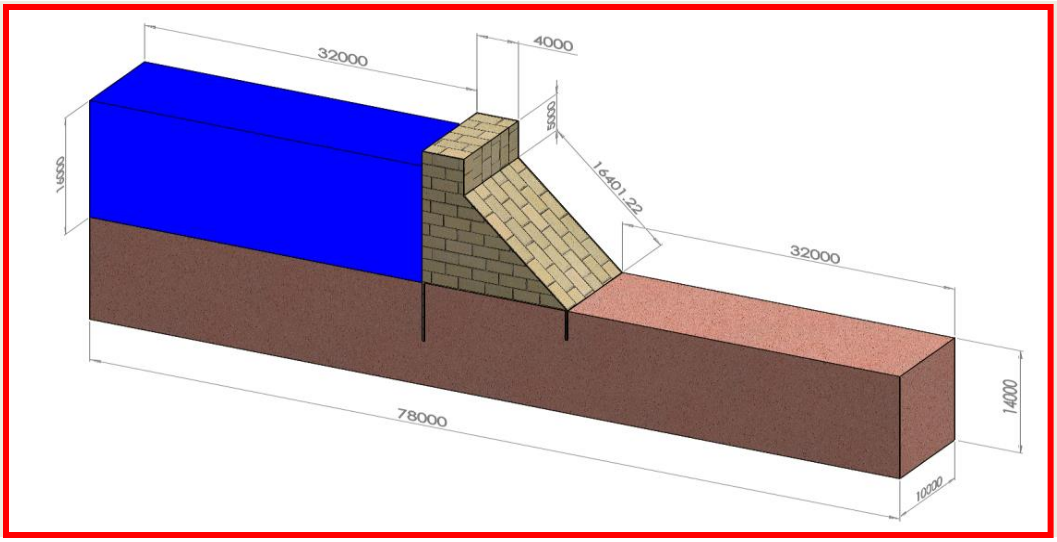


Fig.(3-2): “Schematic of the 3-D considered geometry.”

3.3 The model of hydraulic structure.

The hydraulic structural model for the investigation is a flat floor building with vertical sheet pile embedded in a leaky anisotropic, homogeneous soil base (3-1). The optimal upstream and downstream lengths to satisfy the initial conditions and utilize in the finite element solutions in this work are as follows: where S is the depth of the sheet pile, T is the depth of the domain, and B is the length of the hydraulic structure's floor.

1. H=H1 on the soil surface adjacent to the structure's foundation and H=H2 on the soil surface downstream or after the foundation define the piezometric head's value, respectively. The both sides of the flow domain have a vertical gradient of the piezometric head equal to zero as shown in Fig (3-1).

2. There have been several attempts to calculate the size and scope of the horizontal flow both upstream and downstream. The following equation describes the relationship between the horizontal all along breadth:

$$\text{Error\%} = ((H_n - H_1) / H_1) \times 100 \qquad (3\text{-}9)$$

The flow domain is sufficient if the difference is less than 1%, and the distribution of the piezometric head is only slightly affected by distance [27]. Therefore, 4S is a sufficient distance for this use. The behavior resembles the application of boundary because no flow passes the boundary line, conditions don't exist. The intended outcomes were achieved by simultaneously increasing the average increase on the sheet pile—a fraction of the ground while it is upriver and a lesser elevate resistance on the pile if it is down river reducing the departure slope disperse all along floor at the downstream. The vertical distance of the flow domain from the impervious stratum T, which is larger than the length of the floor, has only a small impact on the dispersal of the piezometric head. To test numerous efforts, the proportion of T to B was set at 1.5, which results in a smaller flow domain on the piezometric head distribution. In this study, the proportion of the primary permeability axis Kmax to the minor permeability axis Kmin is assumed to be 1 in all circumstances, but it is equal to 0 in lenses soil. The current study uses the Anysis program to analyze how the depth of sheet piles affects the leakage hydraulic fluid in homogenous, anisotropic soil's porous medium.

3.4 The boundary of the reservoirs

he following [1] describes the boundary conditions for the general steady state of flow in two dimensions through the soil:

1- Water cannot penetrate the surface of the impervious boundary because the compound vertical velocity of the surface equals zero $(\frac{\partial H}{\partial n}) = 0$, which means that there are no gaps between the surface and the water .

$$k_x (\frac{\partial h}{\partial x})\, i_x + k_y (\frac{\partial h}{\partial y})\, i_y = 0 \qquad (3\text{-}10)$$

where “the i_x and i_y represent the cosine direction of the vertical line on surface with the X and Y direction, respectively. The boundary of this type represents the stream line with constant value for the stream function.”

2- The boundary of the reservoir, the height of the water over these boundaries, and the knowledge of the pressure at any place on these boundaries. Therefore, it is necessary to place the piezometric head along this boundary line in order for all reservoir boundaries to be equivalent to the lines of the piezometric head [1].

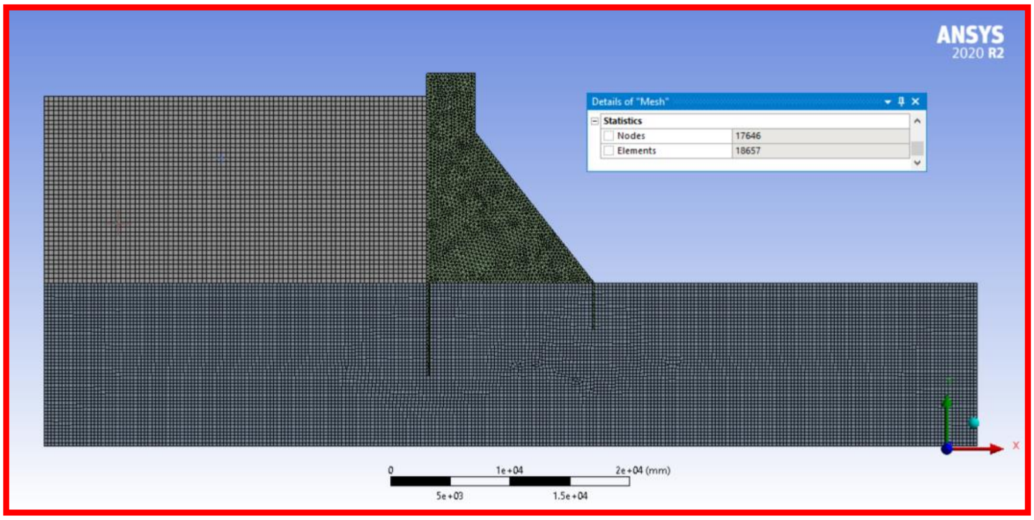
3.5. Mesh Generation

The finite volume numerical coding program is called FLUENT. Mesh creation is needed for the numerical methods' solutions and geometry. The size of the meshes affects how accurate the solutions are (cells). Less dense mesh Size yields more precise results, however as the mesh size is reduced, the number of meshes rises.

Large computational resources and time are consequently needed. Therefore, a compromise between these two issues is necessary. It is necessary to keep meshing up until the answer is grid independent. The drawback of further mesh reduction is the increase in memory requirements.

Tetrahedron or hexahedron cell grids, as depicted in Fig. (3-3), or a combination of the two, can be used by Fluent to create 3-D models. The net pattern to utilize is determined by the application. For problems involving cells with complex geometries, the creation of hierarchical or square grids (made of hexahedrons) might take a long time. A tetrahedron mesh can frequently be created with a great deal less cells than a mesh formed of hexahedron cells since the flow exhibits a wide range of length scales. This is because a tetrahedron mesh allows for cell clustering in specific regions of the flowing fluid. On the other hand, cells are frequently forced to be placed in unnecessary locations in structured hexahedron meshes.

This scenario was chosen for the current investigation of unstructured tetrahedron meshes.



Statistics
Nodes 17646
Elements 18657

Fig.(3-4): The mesh of modle.

4. Results and Discussion.

In this chapter, a numerical model employing "FLUENT LAUNCHER" (2020 R2) is analyzed and discussed. The research will take different sheet pile thicknesses into consideration while looking at water seepage beneath drainage systems. The model has been designed to calculate the effect of seepage water pressure under drainage systems for different distances downstream and upstream of the floor.

4.1 Effect of sheet piles.

Variations in strain and movement throughout hydraulic structures' lowest pressure point, as well as the lowest location of the pressure via sheet piles in porous materials, are explained in Figures (4.1) to (4.6) with the help of two examples. The length-based 4S from the length sheet pile is shown in these photos, together with the length (8m) base pressure distribution at (4m, 8m). The pressure distribution dispersion and speed contours for case one, in which the sheet pile's length (8 m) is positioned below while the sheet pile itself is located upstream, are shown in the figures. At the fastest speed, a plane-like shape of the

velocity flow and pressure was produced (4m).

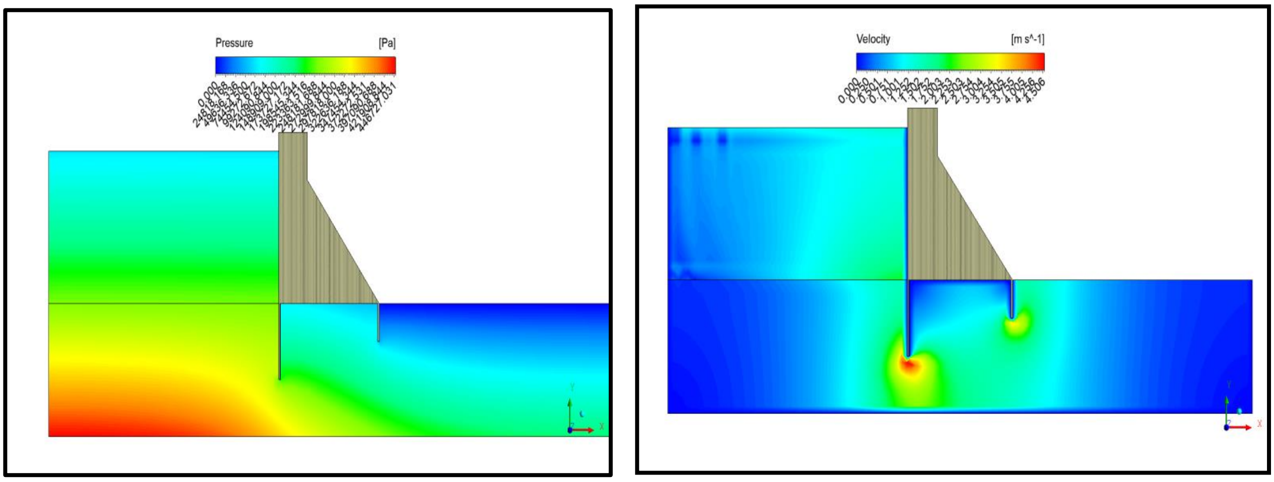


Fig.4-1: “case one pressure and velocity contour with sheet pile 8m length at upstream.”

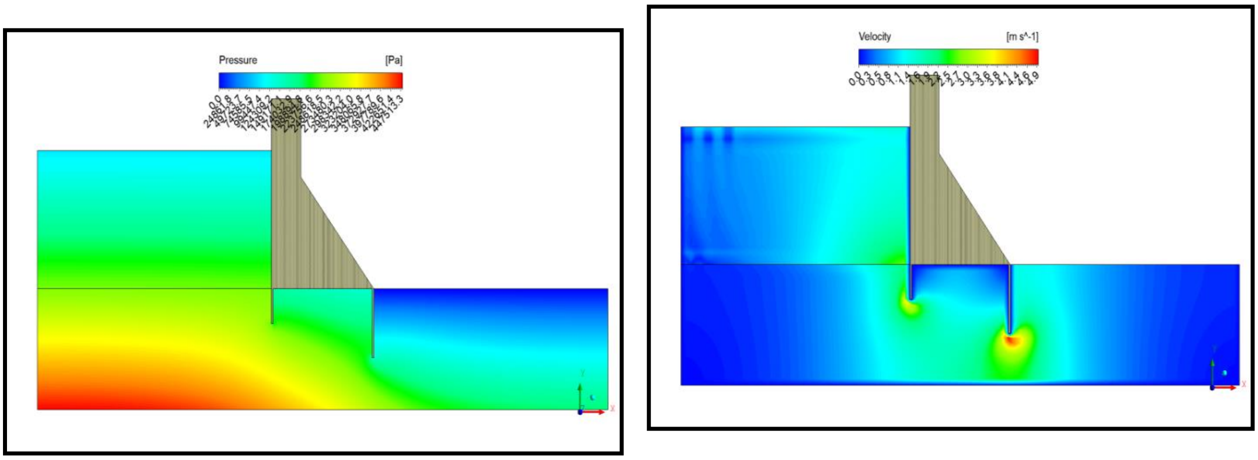


Fig.4-2: “Case two pressure and velocity contour with sheet pile 8m length at downstream.”

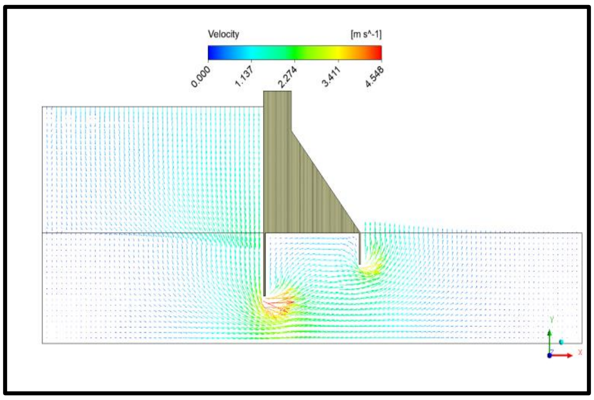


Fig.(4-3): “Shown seepage vector in case one.”

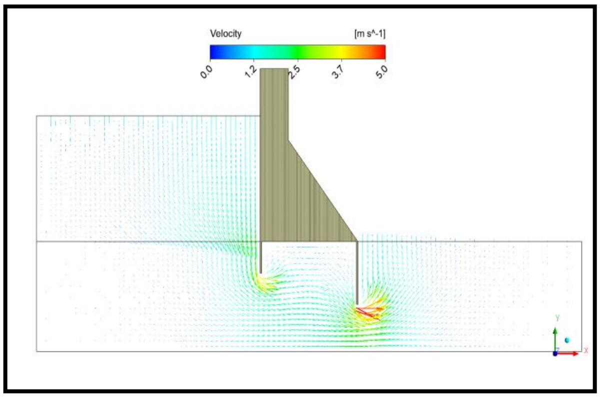


Fig (4-4): “Shown seepage vector in case two.”

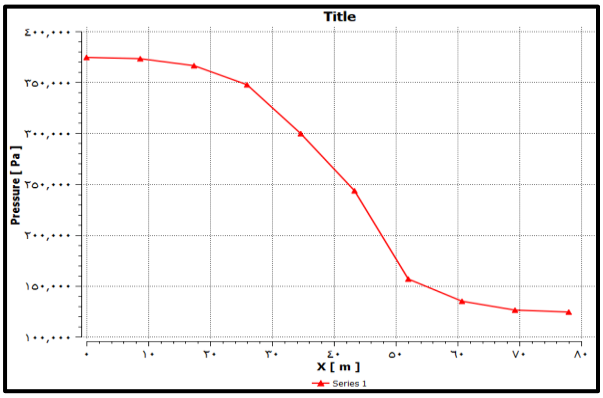


Fig.(4-5): “Shown pressure in case one.”

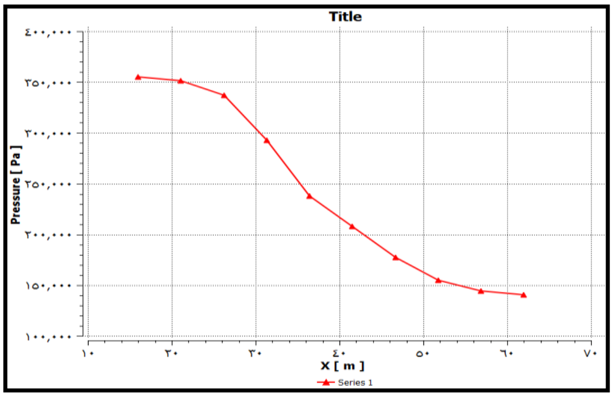


Fig.(4-6): “Shown pressure in case.” two.

4.2 Impact of depth and arrangement on uplift pressure.

The findings are presented to best show the length of sheet piles 8m, when, sheet pile positioned in upstream and the impact of modifying length on pressure drop. Uplift pressure is affected by the depth and arrangement in this section.

Whenever the current floor apron was completely surrounded by the sheet pile on all sides, the departure gradient was greatly reduced. The exit gradient was significantly decreased as a result of a longer in liquid percolation length and a constant differential water head. The structure's safety from piping and percolation is increased as a direct result of this exit gradient reduction. It is evident that it is more effective to drive the sheet pile under the floor at the downstream site than it is to do so at the upstream location.

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