Effect of Impervious Core on Seepage through Zoned Earth Dam (Case Study: Khassa Chai Dam)

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Abstract

One of the main causes of the earth dam failure is the seepage. This seepage can cause weakening in the earth dam structure, followed by a sudden failure due to piping or sloughing, to protect against this failure and for seepage control use impervious zone or core in earth dam. In this work, by applying the finite element method by the computer program SLIDE V.5.0 is applied to determine the quantity of seepage, exit gradient, hydraulic gradient and pressure head of zoned earth dams (Khassa chai dam in Iraq) under effect of changing the core permeability and the core thickness.

Keywords: Zoned Earth Dam, Finite Elements, Flow, Permeability, Core, Seepage.

1 INTRODUCTION

Seepage through earth dam is difficult to analyze especially dams with multiple zones. Therefore, the finite element method is the best tool for analyzing seepage flow in an earthfill dam. Excess quantity of seepage is caused by high permeability, short seepage paths, defects such as cracks and fissures, and by uneven settlements which produce gaps or cracks in the soil or between the structure and the soil. The discharge can be reduced by using soils of low permeability, placing cores in earth structures, cut-off in the foundations, and by increasing the seepage path by employing upstream blankets.

The purpose of the core is to minimize seepage losses through the embankment. As a general rule, sufficient impervious material is available to result in small seepage losses through the embankment. Therefore, the quantity of seepage passing through the foundation and abutments may be more significant than the quantity passing through the core. Important material properties of the core are permeability, erosion resistance, and cracking resistance. A core material of very low permeability may be required when the reservoir is used for long-term storage. A core material of medium permeability may be utilized when the reservoir is used for flood control. The erosion resistance of core material is important in evaluating piping potential. The tensile strength of the core material is important in evaluating the cracking resistance In general, the base of the core or the cutoff trench should be equal to or greater than a quarter of the maximum difference between reservoir and tail water elevations [**U. S. Army Corps of Engineers** (1993)]. An inclined upstream core allows the downstream portion of the embankment to be placed first and the core later and reduces the possibility of hydraulic fracturing [**Nobari, Lee**, and **Duncan** 1973].

Al-Qaisi (1995) presented a numerical analysis of the elastic – inelastic finite element solutions to investigate the behavior of the core of the Adhaim Dam. The effects of core geometry (shape and dimensions) and the relative core stiffness to shell have been investigated. He found that the upstream inclination of the core reduces the generation of pore pressure.

Subuh (2002) presented a mathematical model and applied it for analyzing two–dimensional steady state seepage through stratified and isotropic earth dams. A numerical solution using finite elements method (Galerkin method) was employed to predict the piezometric head distribution, seepage quantity, pore water pressure, and locating the free surface profile.

Fattah, Al-Labban and Salman (2014) used a finite element method through a computer program; Geo-Slope is used in the analysis through its sub-program named SEEP/W. A case study is considered to be Al-Adhaim dam which consists of zoned embankment 3.1 km long. Then several analyses are carried out to study the control of seepage in the dam through studying the effect of several parameters including the permeability of the shell material and the presence of impervious core. It was concluded that the presence of clay core has an important effect on decreasing the exit gradient, which may increase in the order of 300% when the core does not exist.

Karampoorand **Riazi** (2015) used a finite element method through a computer program, named SEEP/W to determine the flow rate that need to time and cost less than laboratory models for analysis of seepage, before the earth dam construction. In their study, Survey effect of the clay core in seepage from nonhomogeneous earth dams by changing of the core permeability, and the results showed the flow rate increases with increasing upstream head and decreases with increasing flow rate through the downstream head. Leakage rate has been reduced to a level 93.72 equal to the core permeability of the 10^{-6} to 10^{-9} , and Leakage flow rate was increased to a value of 92.28%, in the dam has a filter compared with no filter dam. This is due to changes in core permeability of the filter permeability.

2CASE STUDY (KHASSA CHAI DAM)

The Khassa Chai Dam is one of the important earth fill dams in the north ofIraq, the dam is located on Khasa River Upstream the town of Kirkuk. The Khasa Chai river is a tributary of Zaghitun river which is flowing into the existing Adhaim Dam reservoir, The dam site is located near Kuchuk village,10 km northeast of Kirkuk Town. The dam is provided with a central core at its total length is about (2215m) and its maximum height is about (58m), the dam consists of composite section of pervious and impervious materials, the shell (sand and gravel) of the dam will consist of pervious material, and a core (silty clay) of impervious materials. It is a multi-purpose structure designed toMaintain a permanent minimum supply of water into the Khasa Chai river during all seasons for environment improvement and survival of fauna, supply irrigation water for gardens and green yards within the city of Kirkuk and Facilitate the maintenance of recreational water areas within the bed of Khasa Chai course through Kirkuk**(Directorate General of Dams and Reservoirs,(2005))**.

The finite element mesh used in this analysis is shown in Figure (1a). Three node triangle elements are used to describe the domains. The mesh contains (1743) element and (938) node.

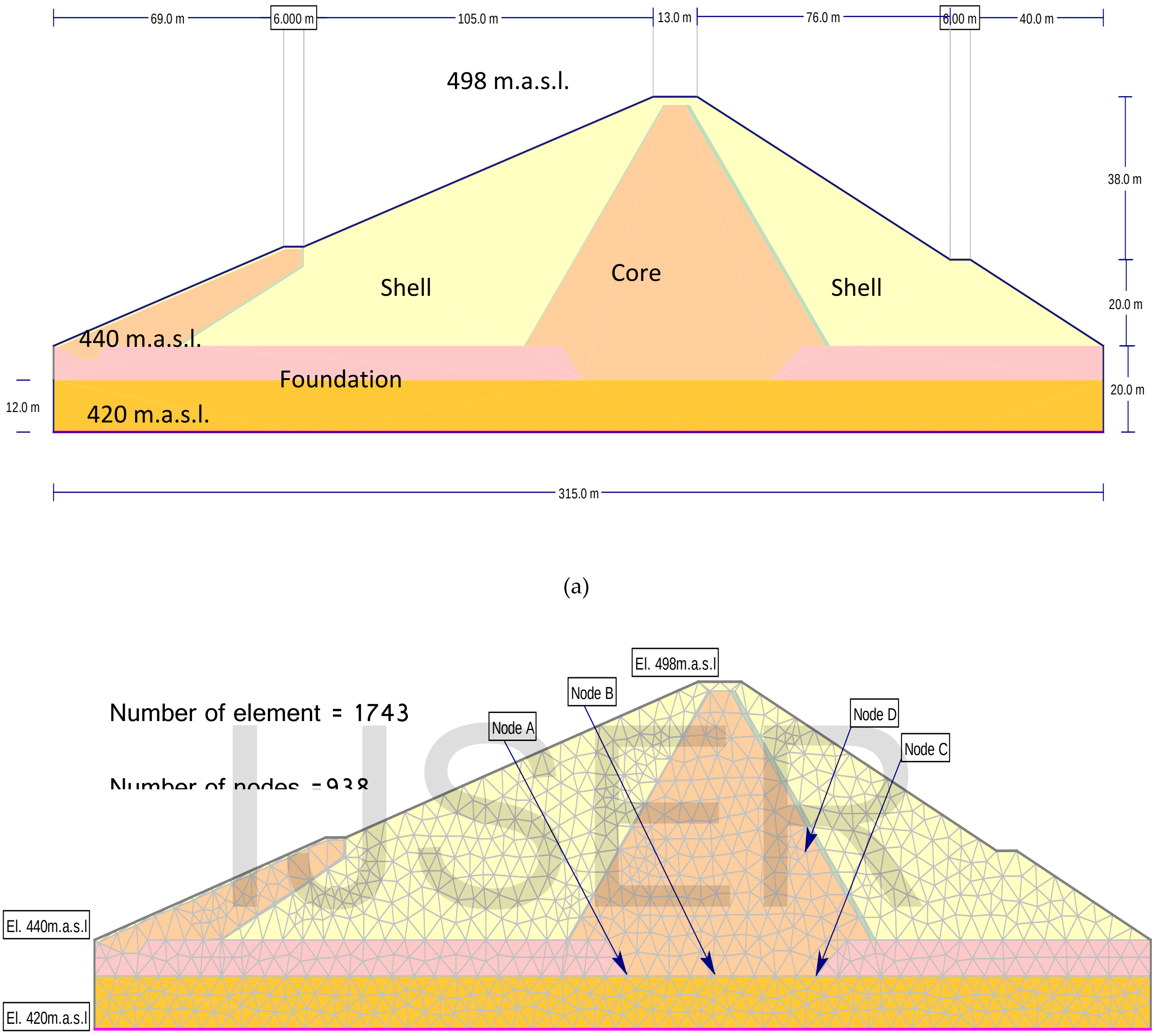

Figure (1) (a) Cross Section of Khassa Chai Dam by Programs **(SLIDE V.5.0)**

(b) Finite Element Mesh for the Khassa Chai Dam

3 RESULTS AND DISCUSSION

3.1 Effect of Changing the Core Permeability

To study the effect of changing the core permeability, different analyses have been made for different values of the core permeability from maximum value (10^{-6} m/s) to minimum value (10^{-10} m/s) for silty clay material [**Azad Koliji**(2013)]and different elevation of water (466, 481 and 495m.a.s.l) where other parameters remained constant**.**

Figure (2) represent theeffect of different values of the core permeability on the quantity of seepage. By changing the core permeability from (10^{-6} m/s) to (10^{-7} m/s), it can be observed that decreasing the value ofthe quantity of seepage by about (9.9-14.69-17.6)% at elevation of water (466, 481 and 495m.a.s.l), respectively, and the quantity of seepage remains constant for the other values.

Figure (3) represent the effect of different values of the core permeability on the exit gradient. By changing the core permeability from (10^{-6} m/s) to (10^{-7} m/s), it can be observed that decreasing the value of the exit gradient by about (40.32-40-40)% at elevation of water (466, 481 and 495m.a.s.l), respectively, and by changing it from (10^{-6} m/s) to (10^{-8} m/s), the value of the exit gradient is decreased by about (15.32-12.5-13.33)% at elevation of water (466, 481 and 495m.a.s.l), respectively, and the exit gradient remains constant for the other values.

Figures (4) and (5), show the effects of different values of the core permeability on the pressure head and hydraulic gradient at node (B) which is located at the center of core base shown in figure (1).When the core permeability is decreased from (10^{-6} m/s) to (10^{-10} m/s), it can be concluded that the hydraulic gradient is increased by about (21.7-17.9-44)% and the pressure head is decreased by about (2.78-3-3.57)% at elevation of water (466, 481 and 495m.a.s.l), respectively.

Figures from (6) to (10) show the phreatic surfaces, discharge sections and flow vectors when the core permeability is changed from (10^{-6} m/s) to (10^{-10} m/s). At the core permeability value (10^{-6} m/s) the phreatic surface would intersect the downstream slope and at values from (10^{-7} m/s) to (10^{-10} m/s) the phreatic line recedes from the downstream slope.

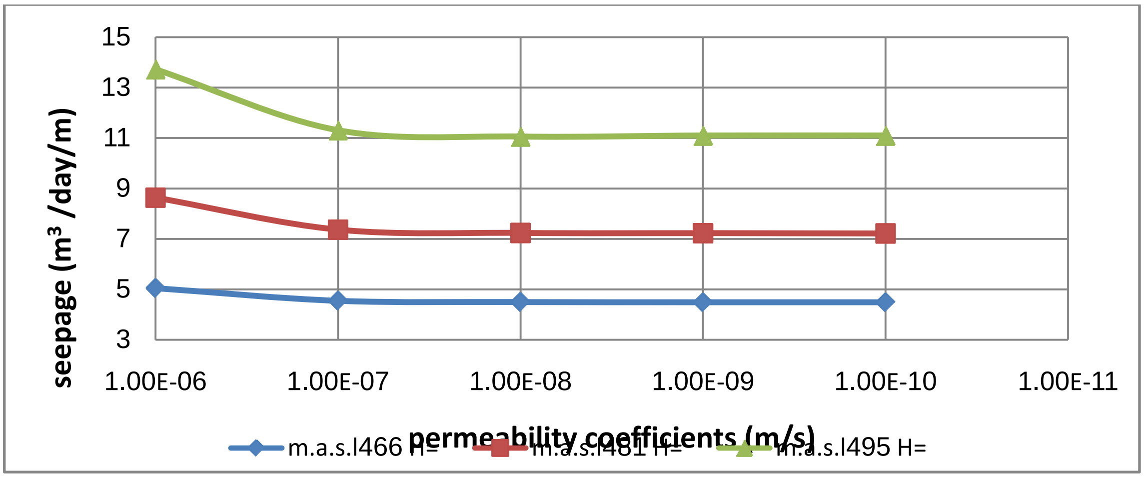

Figure (2) Effect of different values of the core permeability on the quantity of seepage

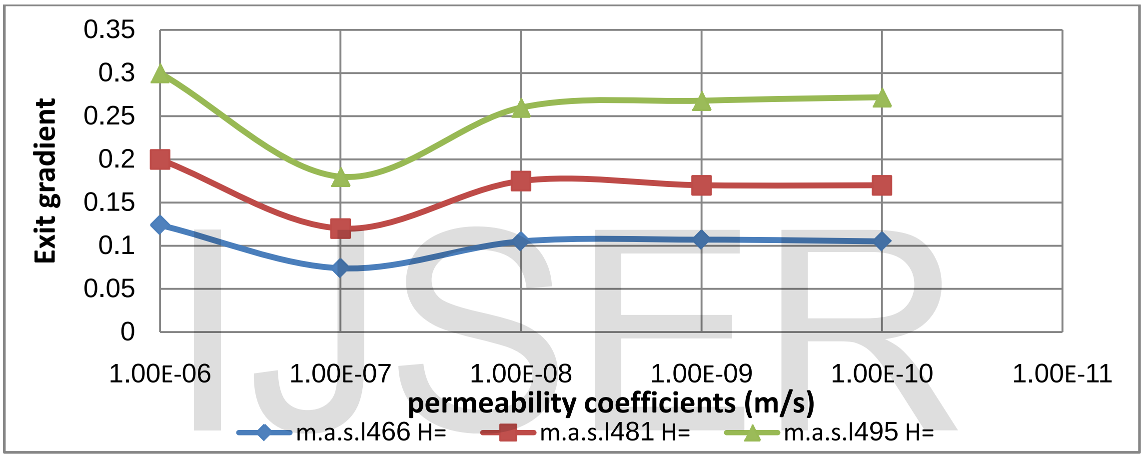

Figure (3) Effect of different values of the core permeability on the exit gradient

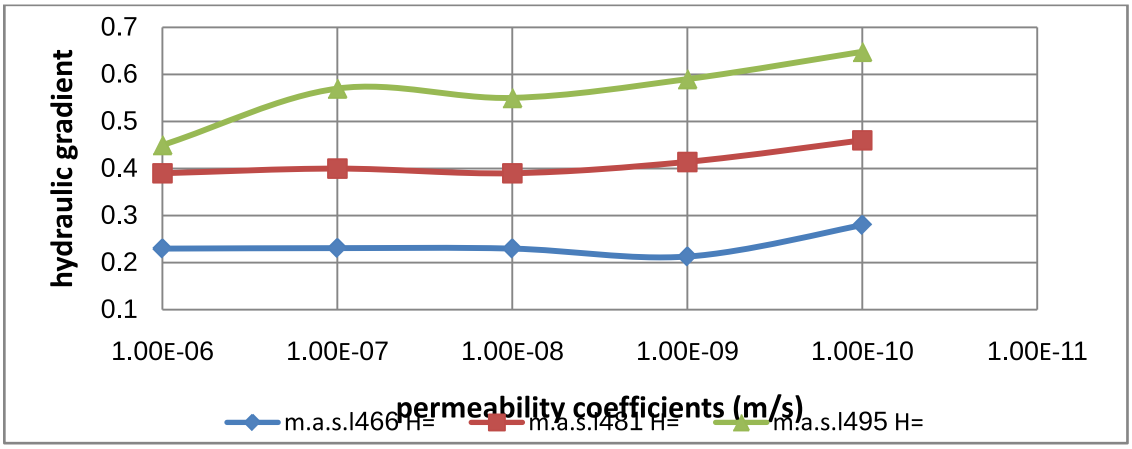

Figure (4) Effect of different values of the core permeability on the hydraulic gradient, at node B

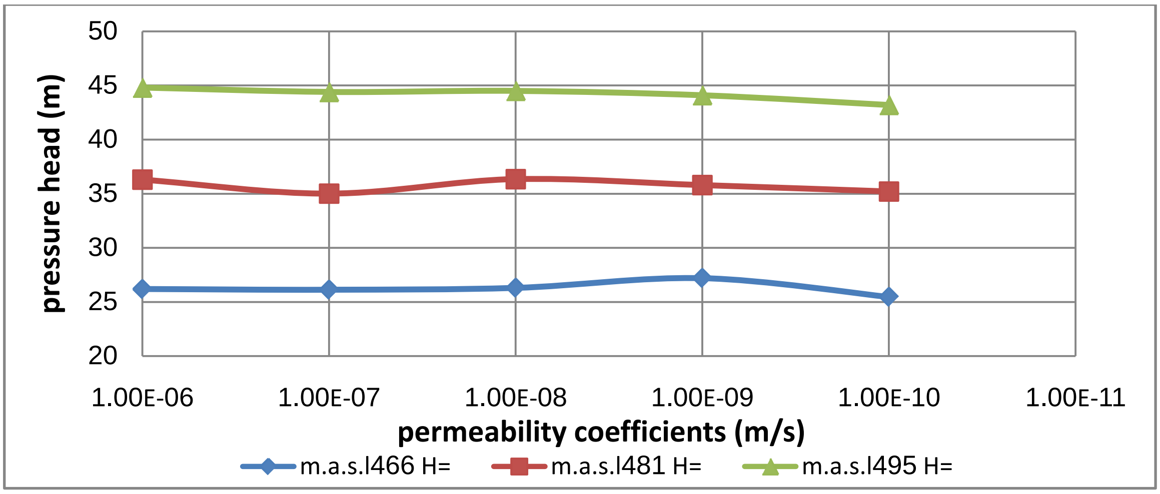

Figure (5) Effect of different values of the core permeability on the pressure head, at node B

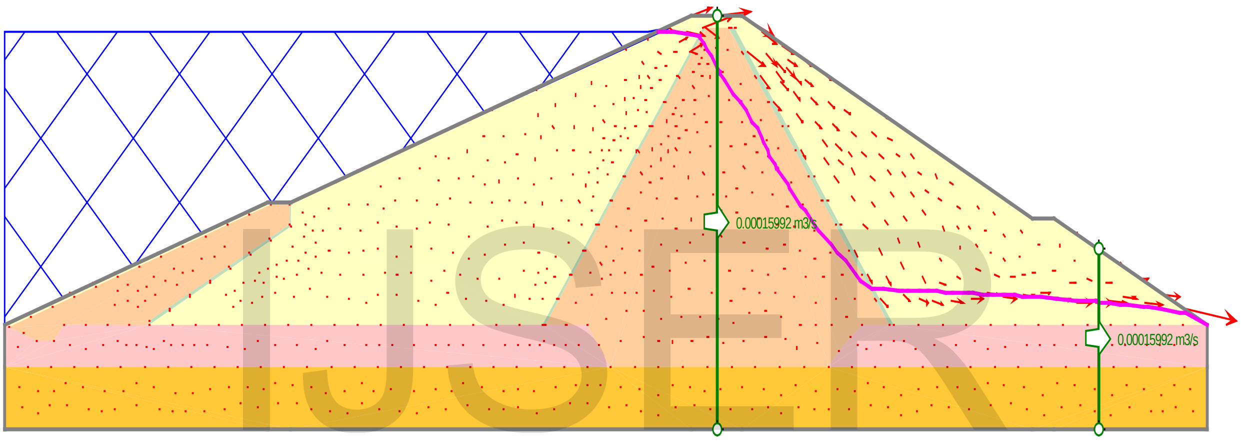

Figure (6) Computed location of phreatic surface, discharge section and flow vectors for maximum water level (495m.a.s.l.),and the core permeability (1x10^{-6} m/s)

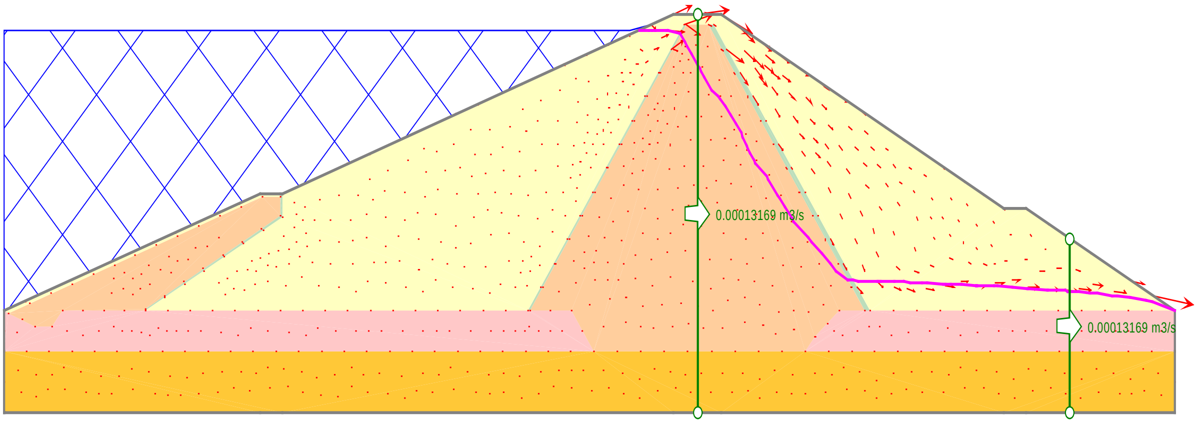

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Figure (7) Computed location of phreatic surface, discharge section and flow vectors for maximum water level (495m.a.s.l.),and the core permeability (1x10^{-7} m/s)

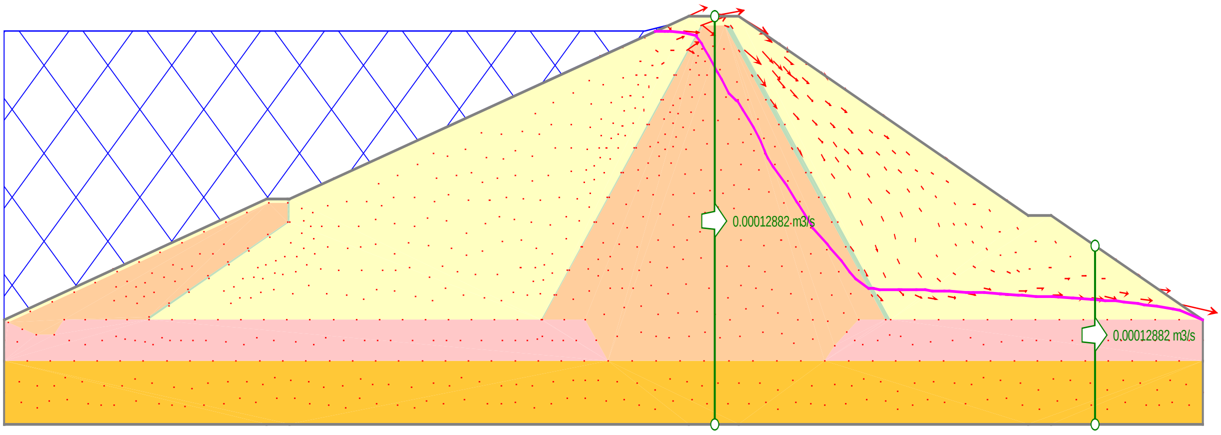

Figure (8) Computed location of phreatic surface, discharge section and flow vectors for maximum water level (495m.a.s.l.),and the core permeability (1x10^{-8} m/s)

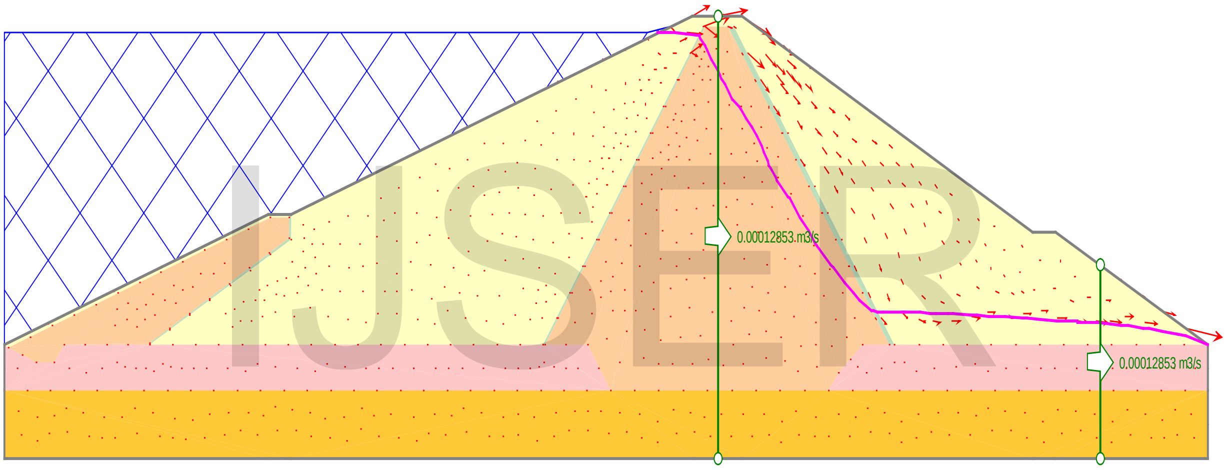

Figure (9) Computed location of phreatic surface, discharge section and flow vectors for maximum water level (495m.a.s.l.),and the core permeability (1x10^{-9} m/s)

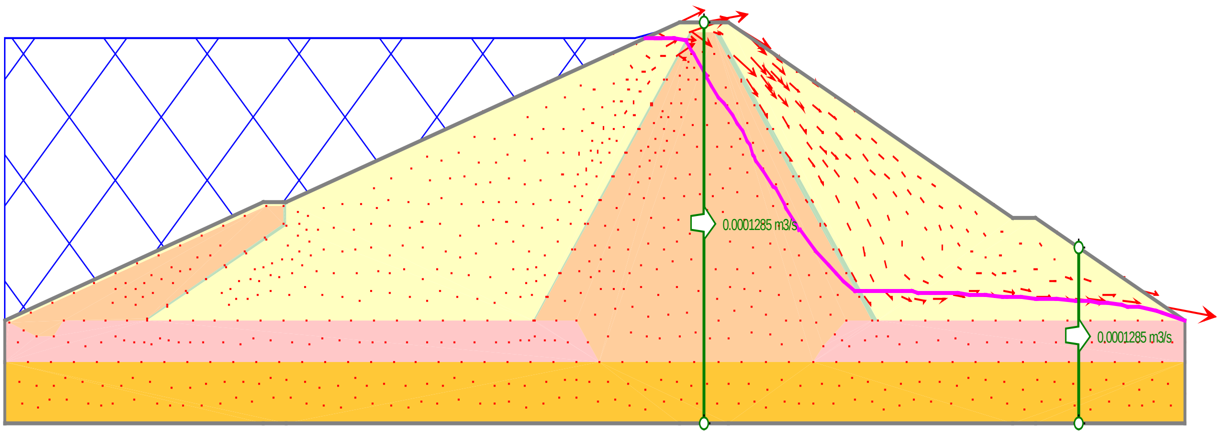

Figure (10) Computed location of phreatic surface, discharge section and flow vectors for maximum water level (495m.a.s.l.),and the core permeability (1x10^{-10} m/s)

3.2 Effect of the Core Thickness

There are several cases studied concerning the core to find the effect of it on the seepage through khassa chai dam, different analyses have been made for different values of water level of reservoir (466, 472, 478, 484 and 490 m.a.s.l) for different values of the core thickness are used, from the actual thickness of Khassa Chai's core (90 m) to (62 m) and (34 m).

Figure (11) shows the relationship between the quantities of seepage at different heads of water by changing of the core thickness. It can be observed that decreasing the value of the core thickness from (90m) to (62m), the quantity of seepage increases between (17.4-15..3)% Also, that decreases the value of the core thickness from (90m) to (34m), the quantity of seepage increases between (32.49-33.36)%.

Figure (12) shows the relationship between the exit gradient at different heads of water by changing of the core thickness. It can be observed that decreasing the value of the core thickness from (90m) to (62m), the exit gradient increases between (50.5%- 11%) Also, it can be observed that decreasing the value of the core thickness from (90m) to (34m), the exit gradient is increasing between (60.4%-20%).

Figures (13) and (14) show the relationships between the hydraulic gradient and the pressure head at different heads at node (B) which is located at the center of core base. It can be found that decreasing the value of the core thickness from (90m) to (62m), the hydraulic gradient is increasing between (36.18%- 33.9%) and the pressure head decreases between (4%- 4.3%), Also, it can be observed that decreasing the value of the core thickness from (90m) to (34m), the hydraulic gradient increases between(125.68%- 117.8%) and the pressure head decreases between (7.4%- 8.11%).

Figures from (15) to (17) show the phreatic surfaces and flow vectors for different water levels. From these figures, it can be concluded that decreasing the value of the core thickness, the phreatic surface is lowered at location of node B.

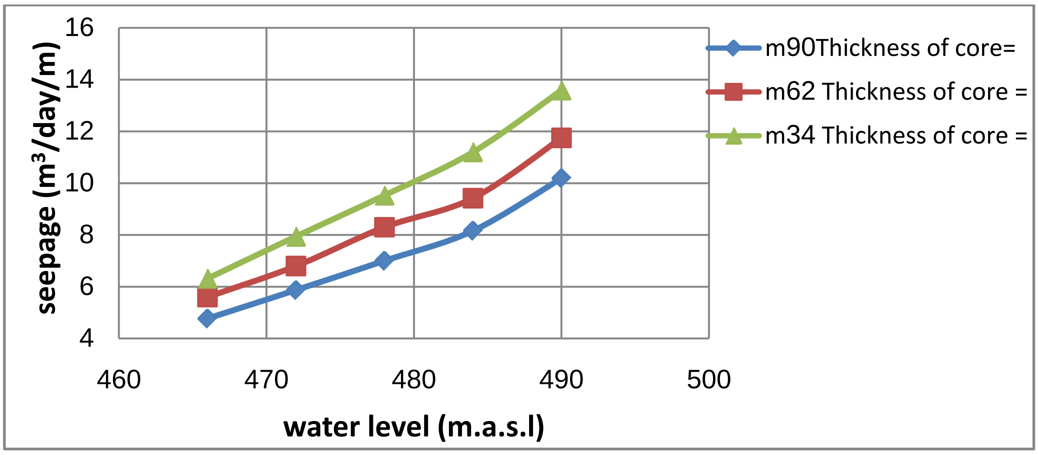

Figure (11) Effect of different values of water level of reservoir on the quantity of seepage by changing of the core thickness

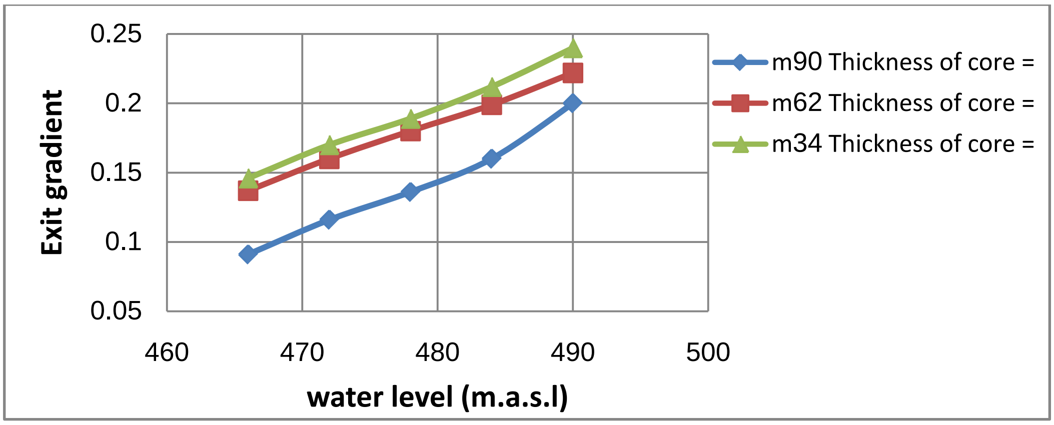

Figure (12) Effect of different values of water level of reservoir on the exit gradient by changing of the core thickness

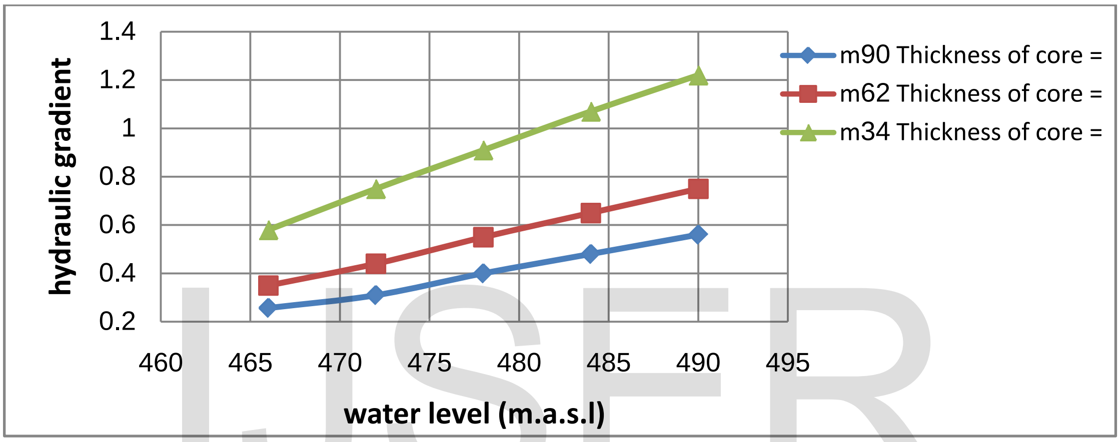

Figure (13) Effect of different values of water level of reservoir on the hydraulic gradient at node B by changing of the core thickness

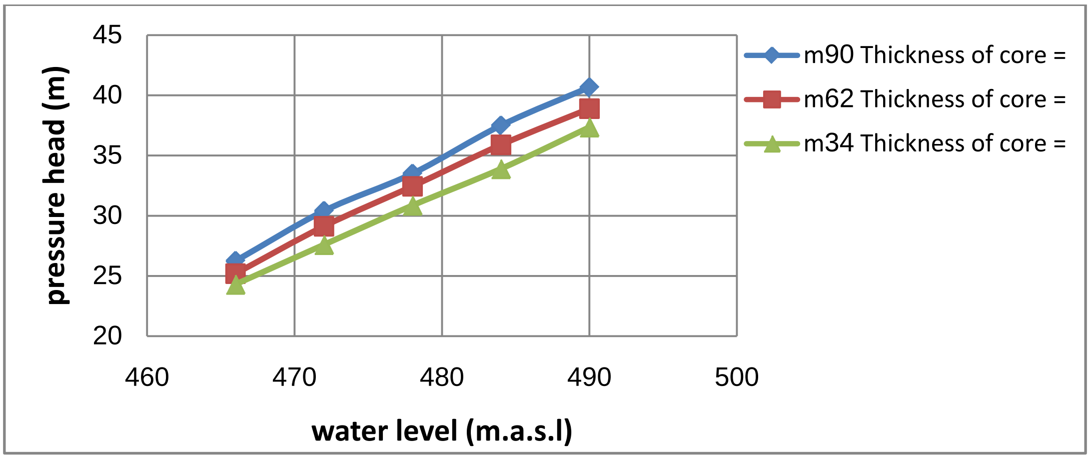

Figure (14) Effect of different values of water level of reservoir on the pressure head at node B by changing of the core thickness

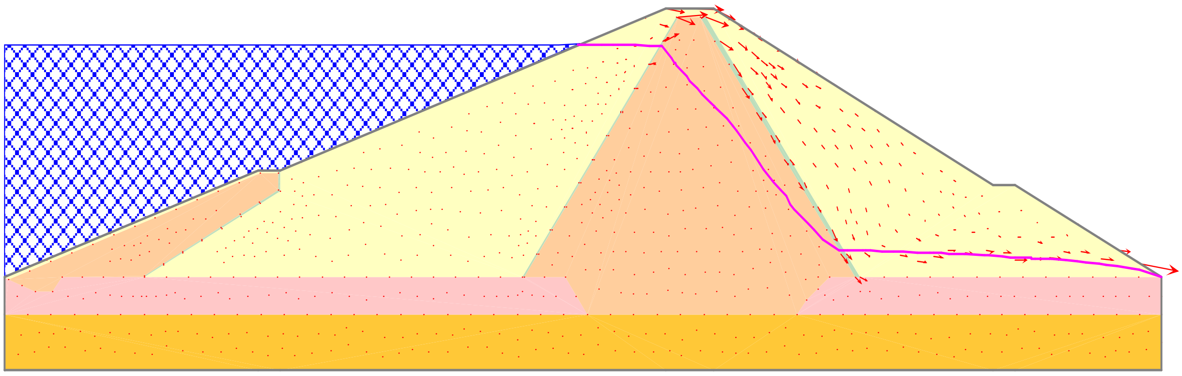

Figure (15) Computed location of phreatic surface and flow vectors for water level (490m.a.s.l.), when the dam is with thickness of core (90 m)

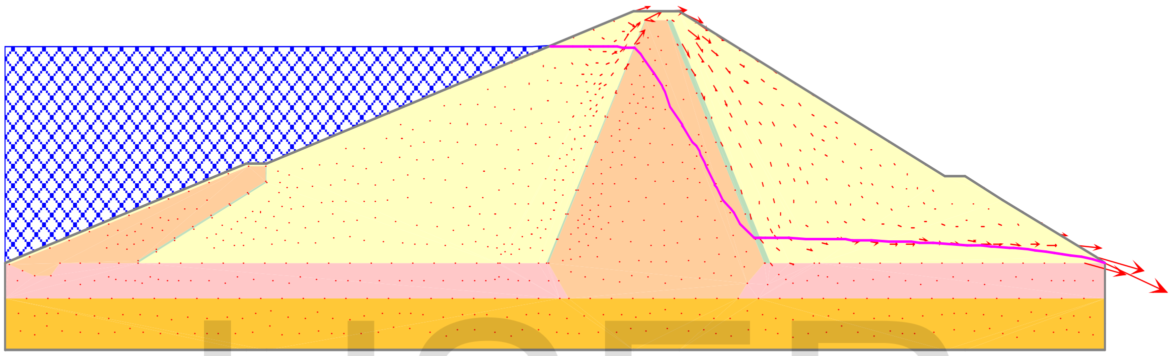

Figure (16) Computed location of phreatic surface and flow vectors for water level (490m.a.s.l.), when the dam is with thickness of core (62 m)

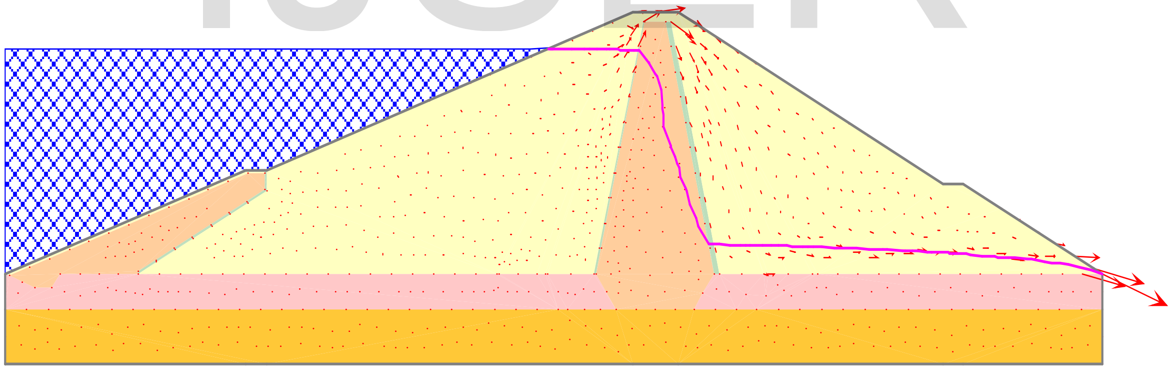

Figure (17) Computed location of phreatic surface and flow vectors for water level (490m.a.s.l.), when the dam is with thickness of core (34 m)

4 CONCLUSION

The presence of clay core has an important effect on decreasing the quantity of seepage and exit gradient, the quantity of seepage and the exit gradient increases when the thickness of core decreases,The core is very necessary in the dam to lower the phreatic surface and decrease the pressure head and seepage through the dam, The sloping core of Khassa Chai dam is the best design for core than other choices since it permits the lowest values of seepage and provides the lowest hydraulic and exit gradients, The minimum value of the core permeability (k core =1x10^{-10}) is the best since it provides acceptable amounts of seepage when the reservoir is used for long-term storage, The medium value of the core permeability (k core =1x10^{-6}) is the best

since it provides acceptable amounts of seepage when the reservoir is used for flood control.

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