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Performance and influence of the injection curtains on characterizations of the infiltration beneath an earth dam

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Abstract

The injection curtain is assumed to be an effective method for reducing infiltration characteristics, such as flow rate, pore pressure, and outlet gradient across the earthen dam foundation. To investigate the influence and performance of injection curtain, the Izdihar dam is selected as a case study for modeling using the numerical analysis software SEEP/W. The objective of this study is to investigate the injection curtain in terms of different numbers and horizontal spacing between injection curtains. The results revealed that by increasing the horizontal distance between the double curtains from the axis under the central core, the flow rate and the exit gradient are decreased while increasing the horizontal distance, the flow rate is decreased by about 20% and the exit gradient is decreased by about 46%. Similarly, by increasing the distance between double curtains to $X/L_{core}=1$, the pore pressure is decreased below the dam. Increasing the number of curtains to three is important for minimizing the outlet gradient and flow rate to optimize the safety of the earth dam, the exit gradient decreases up to 21% and flow rate up to 17%, respectively.

Keywords: Izdihar dam, Infiltration Characterizations, curtains, SEEP/W.

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1. Introduction

The design of a dam is very complex because it is not very repetitive and it is according to the conditions of the site, the foundations, and the available materials of realization that the type of dam is adopted. Based on historical failure cases of the earth dam, the most effective and responsible factors for earth dam failures are structural failure, and seepage problems through the dam body and its foundation. According to a literature study, the most significant seepage characterizations in earth dams are hydraulic gradient, flow rate, and pore pressure. There have been many researches of the cutoff. Recently, (Moharrami et al., 2014) Investigated spacing between two verticals curtains and number of injection curtains against uplift pressure and erosion phenomenon. Their results showed largest spacing between two curtains increased uplift pressure and decreased the gradient, the best number of curtains for decreasing uplift pressure was three. (Meshkabadi and Zandi, 2019) Investigated the effects of various parameters such as the angle of the injection curtain, length, spacing and the number of injection curtains. Investigators studied effect of the cutoff wall depth, (Sartipi et al., 2020), (Shakouri and Mohammadi, 2020) and (Charrak et al., 2021) Investigated impact of the depth of cutoff wall on characteristics of seepage such as outlet gradient, flow rate and uplift pressure. As well, (Norouzi et al., 2020) Investigated the impact of a cutoff wall (permeability, position and depth) with clay core thickness, they found a maximum hydraulic gradient occurs in the cutoff wall and discharge reduction depends on the optimum position. As permeability diminishes and the cutoff wall depth increases. Study depth of double cutoff wall, (Armanuos et al., 2021) Investigated the effectiveness of inclined and depth of dual cut off walls underneath hydraulic structures. They observed that replacing a downstream cutoff wall with a deeper cutoff wall decreased the outlet gradient.

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In this paper, the performance of the grout curtains is investigated under the Izdihar dam by using the numerical analysis SEEP/W software. The purpose of this paper is to conduct an objective investigation of grout curtains in terms of different spacing horizontal and numbers.

2. Materials and methods

2.1 Numerical Model

Figures 1 illustrates the dimensions of the dam and foundation are given in meter. The grout curtains are putted in the axis under the central core, but the analysis is carried out in different spacing horizontal starting form axis under central core, also we considered the numbering of the curtains is started with one to four under the central core. All the cases, mentioned in Table 1.

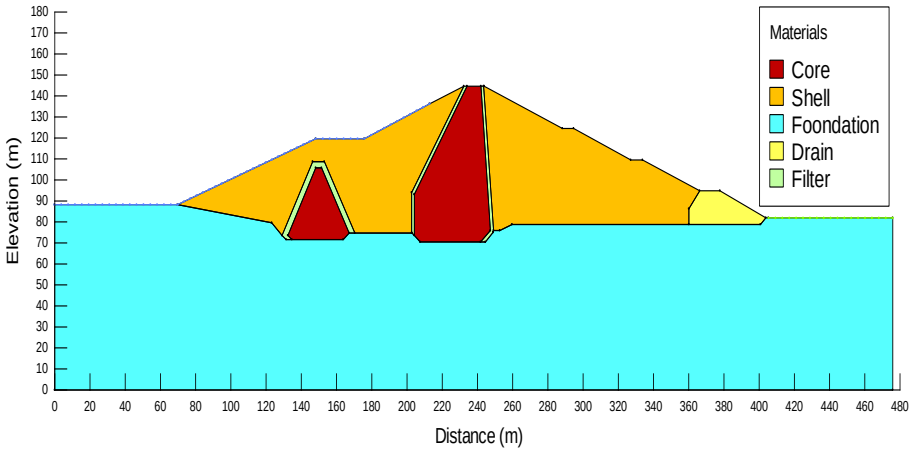

Figure 1. Cross section of the Izdihar dam.

2.2 Simulation process in SEEP/W software

We chose the steady-state to the reservoir at normal level of the dam's water, which is at elevation (48 m), to develop a numerical model for the analysis of seepage using Geo-Slope software (2012). The Simulation procedure in SEEP/W software under Geoslope/W is depicted in Figure 2.

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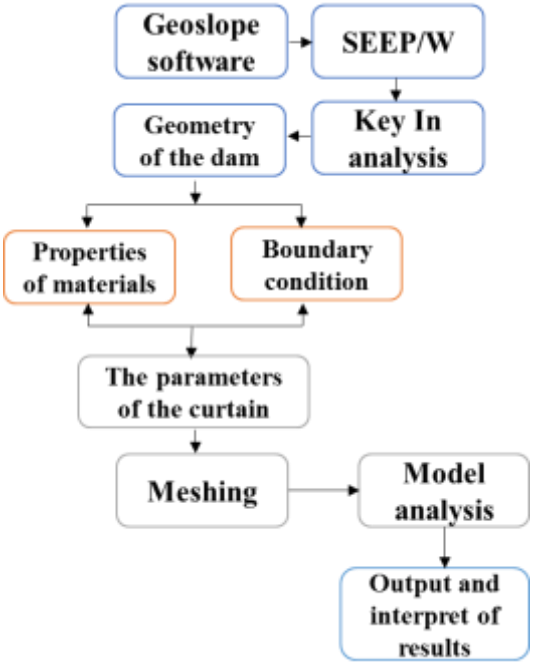

Figure 2. Simulation procedure in the Geoslope/W software.

Table 1. Demonstrates the different parameters of the curation such as the spacing horizontal (X/L_{Core}), (L) is length of central core and numbering of curtains (N).

Cases	1	2	3	4	5
X/L_{Core} (m/m)	0.2	0.4	0.6	0.8	1
N	1	2	3	4	-

When a geometric model is designed in the SEEP /W 2D Software, the production of a finite element model is triggered. Before starting the modeling of the dam in the different scenarios to be processed, a test was performed to modify the mesh according to the desired accuracy. Figure 3 shows the precise mesh size of the dam.

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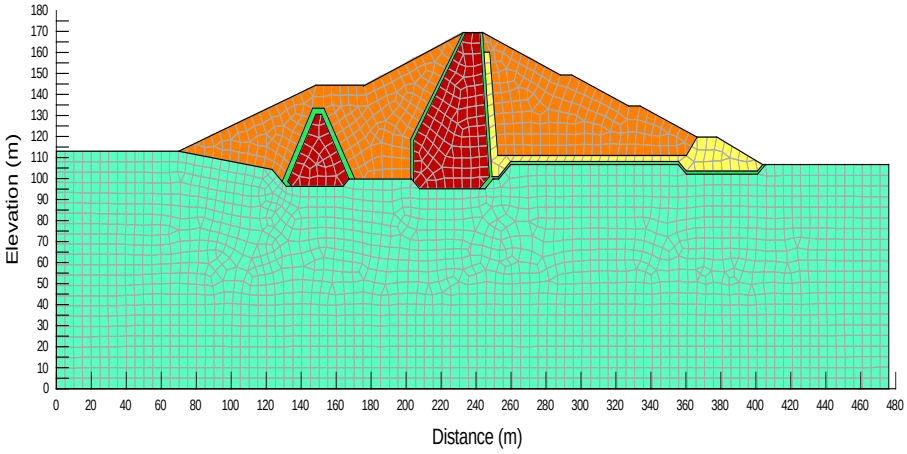
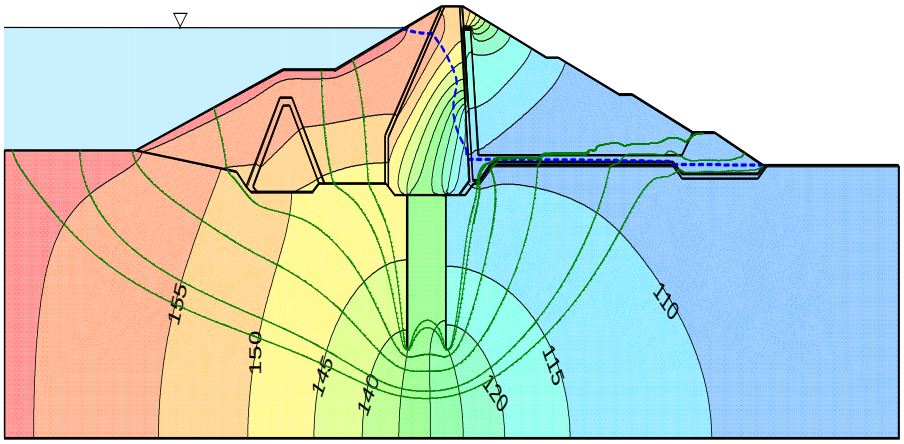


Figure 3. Finite element mesh of the dam.

3. Results and Discussion

3.1 Effect of horizontal spacing between double injection curtains

Spacing is an important parameter when using two or more grout curtains under an earth dam, to study the impact of double grout curtains on flow, hydraulic gradient and pore pressure. The distance considered is the ratio between the space between two grout curtains (X) and the length (L) of the core "R= X/L_{core}", R= (0.2,0.4,0.6,0.8,1 m/m), the depth of the two curtains is 60 m under the central core. Figure 4 shows the equipotential lines, flow lines and Pore pressure, as a function of two grout curtains beneath of the earth dam.



(a)

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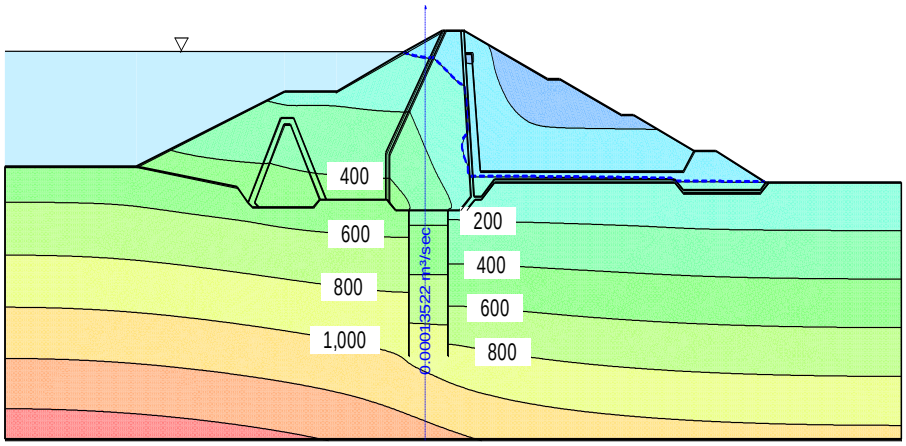

(b)

Figure 4. (a) Equipotential lines and flow lines; (b) Pore pressure and flow rate, as a function of two grout curtains beneath of central core.

Figs 5, 6 and 7 illustrate the results of the influence of the spacing between two vertical grout curtains on the pore pressure, outlet gradient, and flow rate through the earth dam foundation.

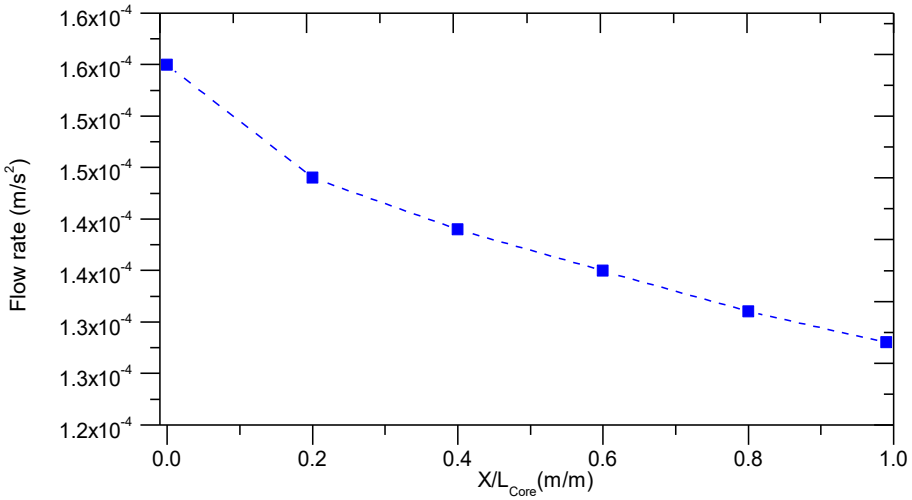

Figure 5. Variation of the flow rates according to the spacing between two curtains.

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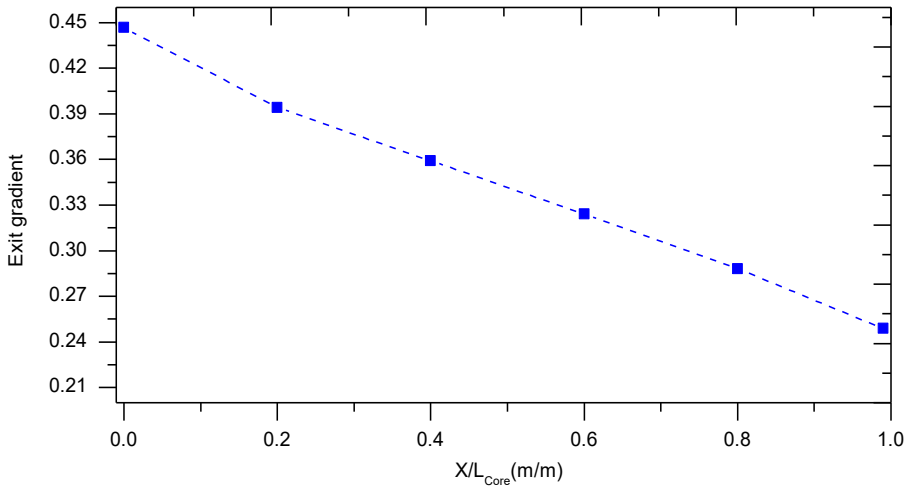

Figure 6. Variation of the hydraulic gradients as a function of the spacing between two curtains.

Figures 5 and 6 show that by increasing the horizontal distance between two injection curtains from the axis under the central core, the flow rate and the output gradient are decreased while by increasing the horizontal distance, the flow rate is decreased by about 20% and the output gradient is decreased by about 46%.

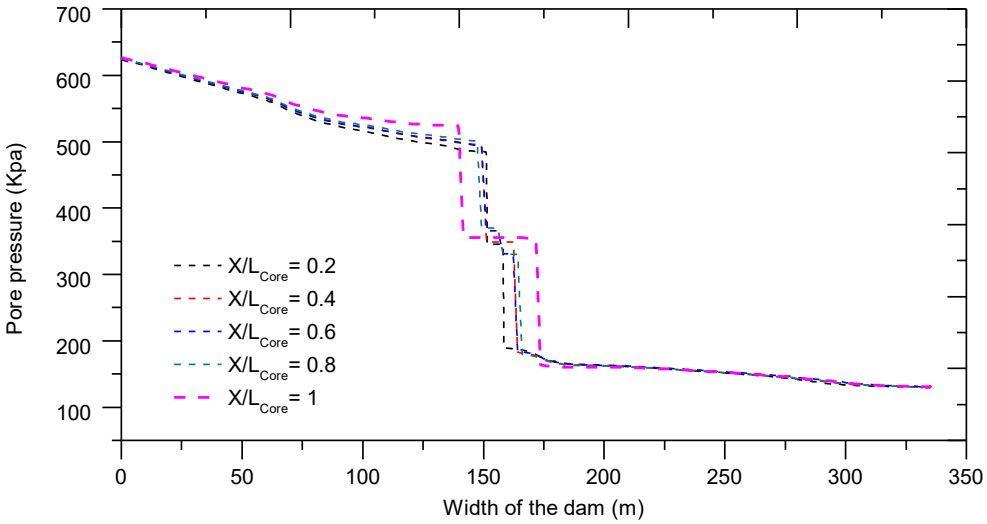

Figure 7. Variation of pore pressures as a function of different spacing between two curtains.

According to figure 7 that a considerable reduction of pore pressures is obtained when increasing the spacing between two injection curtains up to X/L $_{Core}$=1. It is obvious that by increasing the distance between two curtains up to X/L $_{Core}$=1, the pore pressure is decreased under the dam.

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3.2. Effect of the number of sealing Curtains

The effect of the number of grout curtain under the core of the dam with equal depth of curtain D = 60 m and distance between curtains from axis of center core is S = 3 m, and variation of the equipotential lines of the dam. Figure 8 shows the equipotential lines and numbering of grout curtain below the dam.

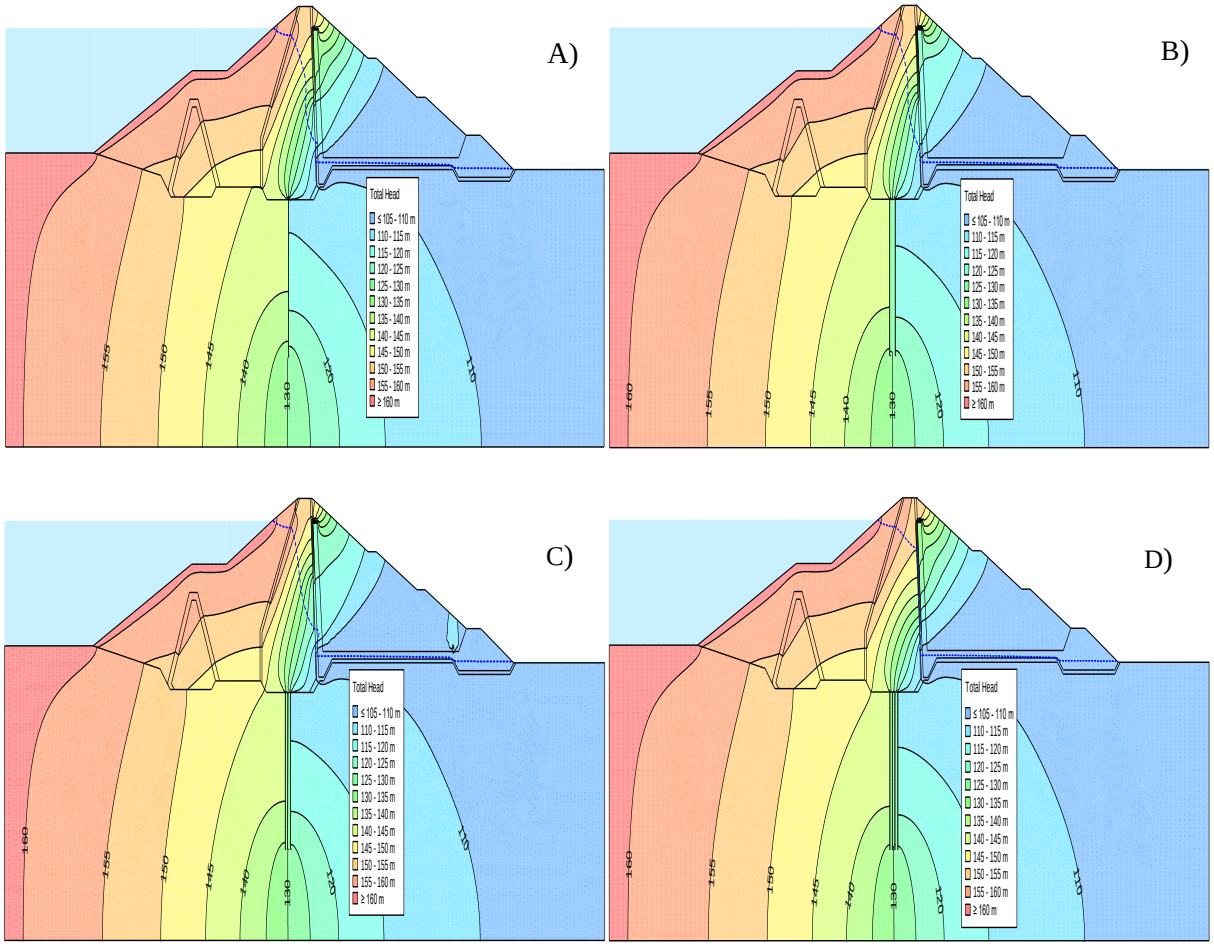

Figure.8 Equipotential lines and numbering of grout curtain below the dam; **A)** $N_{Curtain} = 1$, **B)** $N_{Curtain} = 2$, **C)** $N_{Curtain} = 3$, **D)** $N_{Curtain} = 4$.

Effect of the number of sealing curtains beneath a center core with depth of 60 m and the horizontal spacing 3 m on max outlet gradient and flow rate with different number of the curtains 1,2,3 and 4 are illustrated in figure 9 and 10.

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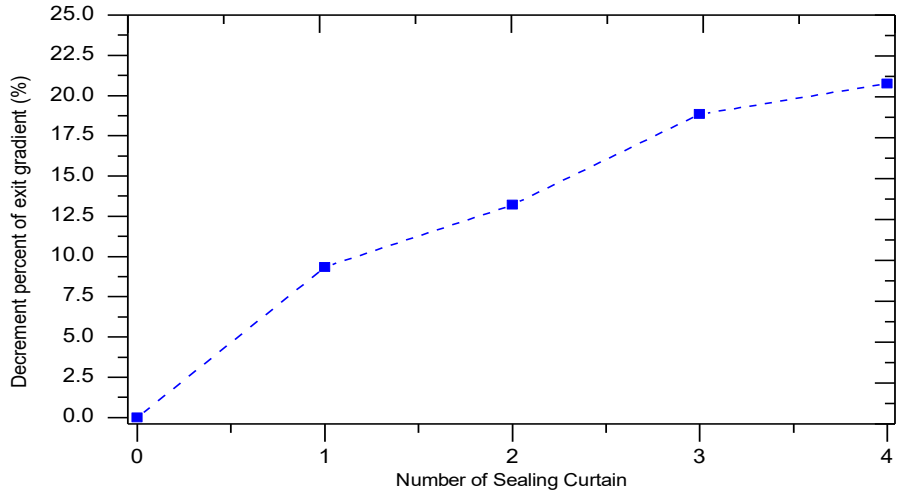

***Figure 9**. Decrement of maximum outlet gradient alongside the downstream side with various numbers of curtains.*

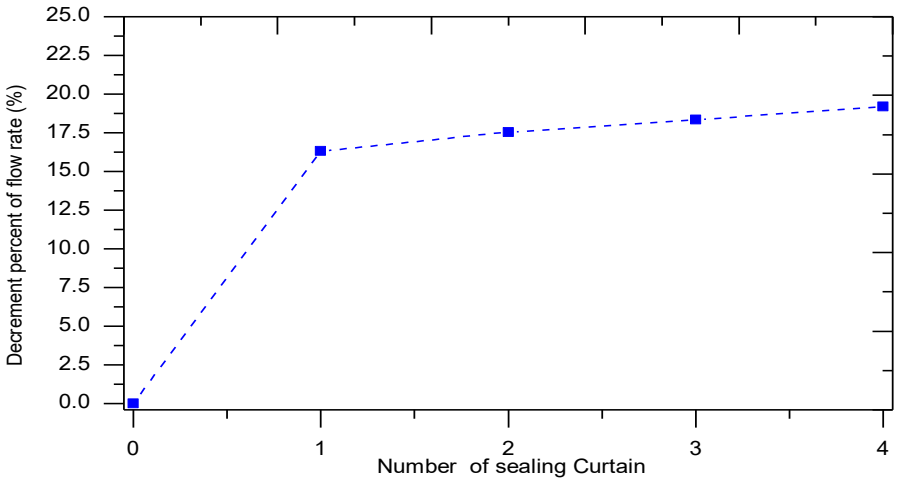

Figure 10. Decrement of flow rate an extended foundation with various numbers curtains.

According to figure 9, the value of the max outlet gradient 0.85 decreases 10,13,19 and 21% respectively, when an increase the numbers of the curtain. Hence, increasing the numbers of curtain is important to minimize max outlet gradient. According to figure 10, the value of the flow rate 2.45E-4 m^2/s, through the foundation decreased about 17 % when used one curtain also decrease slightly 17.5,18.5 and 19.5 %, when 2,3 and 4 numbers of the curtains. The number appropriate to diminish the flow rate and piping phenomenon is three under a downstream core.

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4. Conclusion

To investigation influence the performance of grout curtain for decreasing characterization of seepage under the dam, the spacing horizontal and depth of grout curtain were considered to optimize the security choices of the dam. The parameterized study carried out on the Sidi Abdelli dam enabled the conclusions and recommendations below to be drawn up:

- By increasing the horizontal distance between two injection curtains from the axis under the central core, the flow rate and the output gradient are decreased while by increasing the horizontal distance, the flow rate is decreased by about 20% and the output gradient is decreased by about 46%.
- A considerable reduction of pore pressures is obtained when increasing the spacing between two injection curtains up to $X/L_{core}=1$. It is obvious that by increasing the distance between two curtains up to $X/L_{core}=1$, the pore pressure is decreased under the dam.
- Outlet gradient decreases 10,13,19 and 21% respectively, when an increase the numbers of the curtain. Hence, increasing the numbers of curtain to three is important to minimize outlet gradient.
- The flow rate through the foundation decreased about 17 % when used one curtain also decrease slightly 17.5,18.5 and 19.5 %, when 2,3 and 4 numbers of the curtains. The number appropriate to diminish the flow rate and piping phenomenon is three under a downstream core.

Acknowledgment

No conflict in this article

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