4th International Engineering Conference on Developments in Civil & Computer Engineering Applications 2018 (ISSN 2409-6997)

INFLUENCE OF UPSTREAM BLANKET ON EARTH DAM SEEPAGE

Krikar M-Gharrib Noori[1], Hawkar Hashim Ibrahim[2], Dr.Ahmed Mohammed Hasan[3]

[1]*Koya Technical Institute, EPU, Koya, KRG-Iraq*
[2&3] *College of Engineering, Salahaddin University-Erbil*
[1]*Krikar.bedary@epu.edu.krd*, [2]*hawkar.ibrahim@su.edu.krd*, [3]*ahmed.hasan@su.edu.krd*

doi:10.23918/iec2018.14

ABSTRACT

Seepage is one of the main causes of earth dam failure. Concerning the failure, the control of seepage is required. In this study, the analyses of seepage problem were performed on Shiwashok earth dam body and its foundation. This study has concentrated on the efficiency of using upstream blanket to reduce seepage discharge and the uplift pressure of Shiwashok earth dam in Kurdistan region of Iraq. To meet the aims of this study, different clay blanket lengths and thicknesses were investigated. Two dimensional simulations of 23m high Shiwashok earth dam were carried out using the numerical analysis SEEP/W software using existing data of the geometrical and mechanical properties of the earth dam and its foundation. The outcomes showed that lengthening the clay blanket and increasing blanket thickness reduced the percentage of seepage amount and uplift pressure at the downstream side of the dam. It can be concluded from the results of the simulations that the optimum blanket length (BL) and the blanket thickness (t) were 80m, and 1m to 1.5m, respectively.

Keywords: Seepage Control, Clay Blanket, Shiwashok Earth Dam, SEEP/W.

1. INTRODUCTION

Embankment dams are primarily built from compacted soil or rock. They are the principal means of storing water[1]. When the embankment dams are impounded with water, they are subject to seepage through their embankments and foundations. Seepage is considered one of the common reasons that cause failure in earth dam [2]. There are many different methods to decrease and control the seepage discharge at the foundation of embankment dams such as grout curtain, concrete wall, slurry trench, cutoff wall, upstream blanket, filters, sand drains, and relief wells [3], [4]. The selection of the seepage control approaches is based on some aspects including material availability, cost, soil type, construction access, machinery availability, and construction access [5]. Each of these approaches has its own, technical, economical and practical limitations. For example, in a case that the reservoir head exceeds 200 ft (60.96m) upstream blankets should not be used because the hydraulic gradient acting across the blanket may result in piping and serious leakage [6]. Therefore, using any of the seepage control approaches or a combination of them can be provided with the foundation condition and the practical limitation considerations.

Rezk and Senoon [7] calculated the seepage problem of earth dam with upstream blanket analytically to evaluate the effect of the blanket length on each of seepage and head loss. It was recommended to apply mathematical solution to find seepage discharge and head loss for earth dam with upstream blanket. It was recommended to apply a mathematical solution to find seepage discharge and head loss for earth dam with the upstream blanket. It was found that the mathematical solution could be validly applied for the relative depth of the upstream impervious layer (d/L) ratio ranging from 0.014 to 0.164. In Goharnejad, et al. [8] study the effects of upstream clay blankets in terms of geometry, and dimensions were examined to reduce the seepage in the foundation of Farim Sahra Dam in Iran. According to the results, upstream blanket considerably decreases seepage discharge and the upstream clay blanket with 0.75 m thickness and 150 m length suggested. In this case, the seepage amount is about 73% less than the amount when there is no clay blanket, and the possible applied thickness is at least 0.75m, which might be changed according to the topographical situation.

This study concerns about investigating of Shiwashok earth dam, which has already designed without clay blanket, which is not constructed yet. To avoid failure of the dam, before construction, checking stability and re-designing of the dam is crucial. For that reason, in this paper, the effects of various upstream blanket lengths and thicknesses on seepage discharge and uplift pressure were studied. Numerical simulation carried out using SEEP/W software used to study seepage in Shiwashok earth dam.

2. MATERIAL AND METHODS

2.1 SEEPAGE THEORY

SEEP/W is formulated on the basis that the flow of water through both saturated and unsaturated soil follows Darcy's Law [9]:

$$q = kiA \tag{1}$$

where q is the specific discharge, k is the hydraulic conductivity, i is the gradient of total hydraulic head and A is cross-sectional area of flow. The rate of underseepage may be estimated for pervious foundation, which is cut off by a clay blanket by [10]:

$$\frac{Q_o}{K_o\ H} = \frac{1}{0.88 + \left[\frac{B + BL}{D_f}\right]} \tag{2}$$

where Q_o is rate of underseepage in m/sec per running meter of dam, K_o is permeability of the foundation in m/sec., H is head of water in the reservoir in m, B is width of the base of the core in m, D_f is depth of the foundation in m, and *BL* is Blanket length.

2.2 NUMERICAL SIMULATION

In this study, for the purpose of seepage analysis through a heterogeneous earth dam, Shiwashok zoned earth dam was taken to model as a case study. It is 23 m height, its crest crown is 7 m wide and the base width of the dam is 136 m. The reservoir water level is 20 m high faces the upstream side. The upstream face of the dam has a slope of 1:2.75 while the downstream slope of the dam designed to have a 1:2.5 slope with 2 m berm and its height is 12 m from the base level. The downstream slope is flattened to 1:2.75 in the downward direction below the berm elevation. A cofferdam with 11 m high and 4 m width crest will be a part of the main dam body while its crest will be a berm for the upstream slope. The upstream face of the cofferdam has a slope of 1:2.75, while the downstream slope of the cofferdam designed to have a 1:2.25 slope. The crest of the core is at 22 m high and its width is 4 m. It will expand with a slope 1:3.75 to the foundation to reach about 15 m at a lowest level of the dam. The filter material was used on the downstream side and extends along the downstream side foundation. The hydraulic conductivity of the dam components is described in Table 1.

TABLE 1.
The permeability of the materials used in the components of the dam

Types of materials	Permeability (k)
Shell	$1 * 10^{-6}$ m/sec
Core	$3 * 10^{-9}$ m/sec
Filter	$5 * 10^{-4}$ m/sec
Foundation	$1 * 10^{-6}$ m/sec

Using the numerical analyses of SEEP/W software and having the mechanical and geometrical properties of the dam and its foundation, two-dimensional simulation of Shiwashok earth dam with 25 m assumed alluvial foundation was carried out. The study was performed to investigate the effects of the upstream blanket with the same permeability of the core (k = 3*10-9 m/sec), on the seepage amount and uplift pressure. The parameters used in analyses are the thickness of the blanket (t), and the length of the blanket (BL). Figure 1 shows Shiwashok earth dam cross section with and without clay blanket.

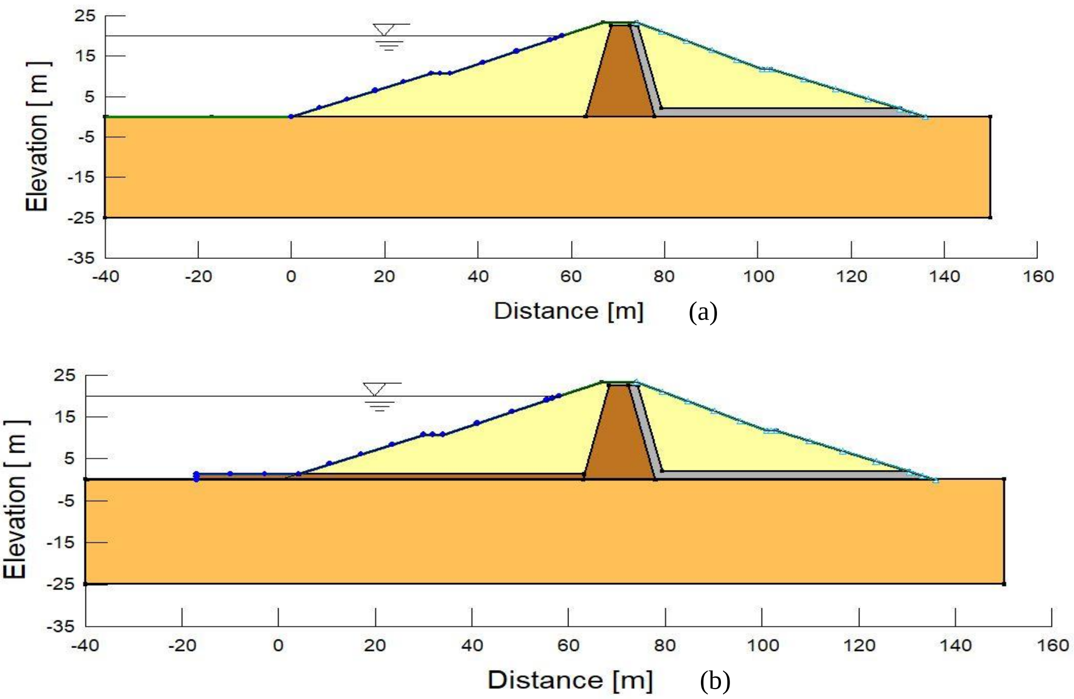


FIGURE 1. Cross section of Shiwashok earth dam used in this study
(a) without clay blanket (b) With clay blanket

3. RESULTS AND DISCUSSION

Seepage analysis performed, considering geometrical parameters and material properties of Shiwashok earth dam, using the SEEP/W software (GeoStudio 2007). To mesh the models, rectangular elements with 4-nodes as well as 3-node triangular elements were considered. Results from different models, compared and discussed extensively to select the best model. The results included the seepage reduction, the quantity of seepage through the dam, the pore water pressure distribution, and the effects upstream blanket. Since cutoff trenches are not essential or are quite costly, an upstream blanket tied into the core of the dam and was used to reduce underseepage. In order to investigate the effects of the clay blanket on the seepage reduction, and pore water pressure, various clay blanket lengths with different thickness were used. The blanket lengths that used in this study were (55m, 80m, 105m, and 130 m).

The study demonstrates that for a constant blanket thickness, the percentage of seepage amount reduced due to the increase in the length of the clay blanket. Lengthening the clay blanket caused an increase in the length of the water flow path and thus induced a decrease in the hydraulic gradient and uplift pressure at the downstream side of the dam. This, in turn, caused a reduction in the velocity and therefore a decrease in the discharge at the dam foundation.

Figure 2 shows the reduction of seepage as a result of an increase in the length of the blanket for different blanket thickness and compared with the curve plotted by the USBR [10]. It is clear that obtained curve from the SEEP/W for the blanket thickness of 2.5 m has slightly difference with the USBR (2014) designed curve but a great difference can be noticed for a dam with the thickness of 0.5 m . It is important to note that the blanket lengths with less than four times the reservoir water depth ($BL/H < 4$) reduce seepage considerably; however, it is also noticeable that the longer blanket length does not have a significant effect on the percentage of seepage quantities and seepage reduction. Hence, the determined length for upstream the blanket can be suggested as four times the water level height.

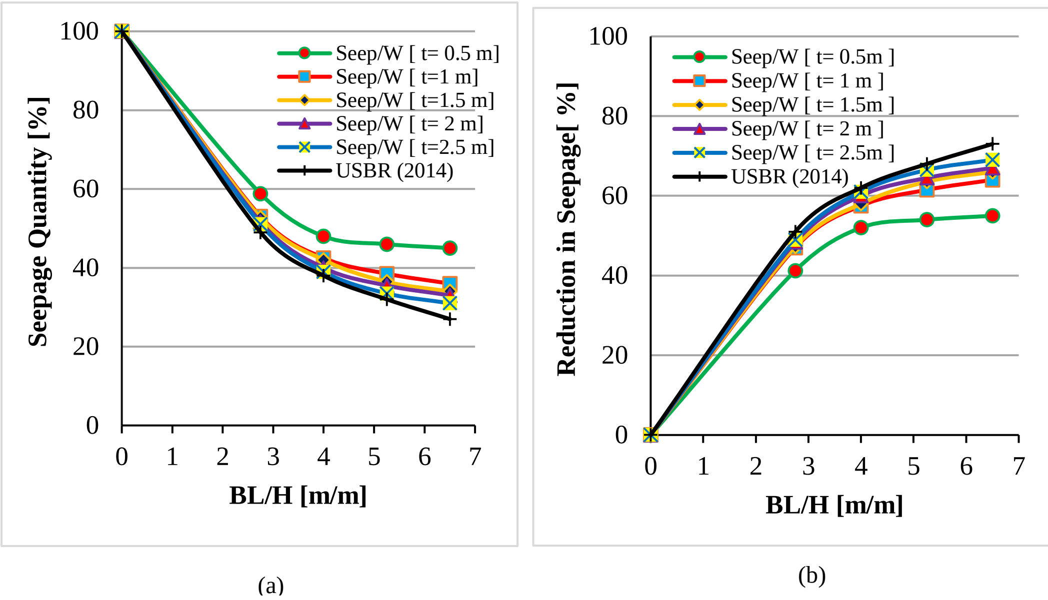


FIGURE 2. Shows the relationship between the percentage of (a) seepage quantity and (b) seepage reduction with the ratio of blanket length to the water head (BL/H) for different blanket thicknesses compared to the curve plotted by [USBR [10]].

As far as the blanket thickness is concerned, five cases have been considered for the study. The outcomes indicated that increasing the blanket thickness could play a significant role to reduce the seepage discharge. Figure 3 explains the effect of the blanket thickness with different lengths in the reduction of seepage in the dam foundation. Subsequently, increasing in blanket thickness causes decrease the seepage discharge. It can be seen that the blanket thicknesses of more than 1.5 m do not have a considerable effect in seepage reduction. Therefore, it is important to note that the blanket thicknesses between 1m to 1.5m are a good choice for reducing seepage quantities.

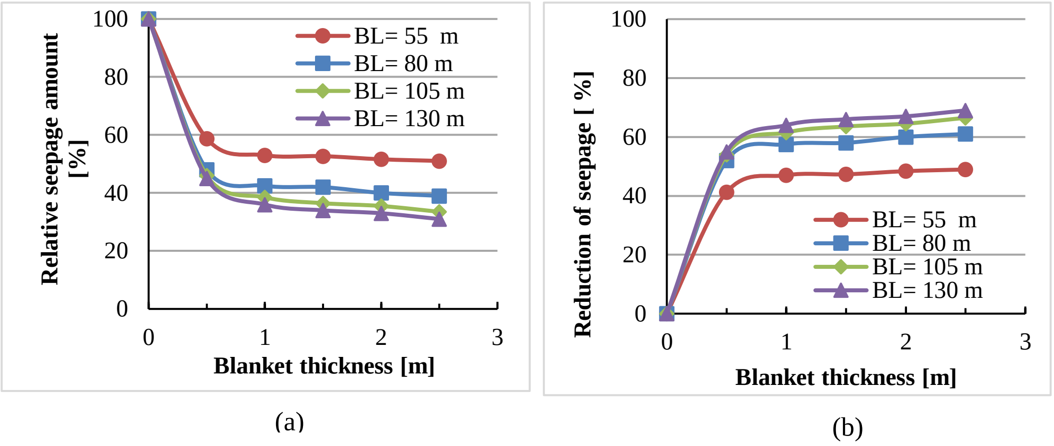
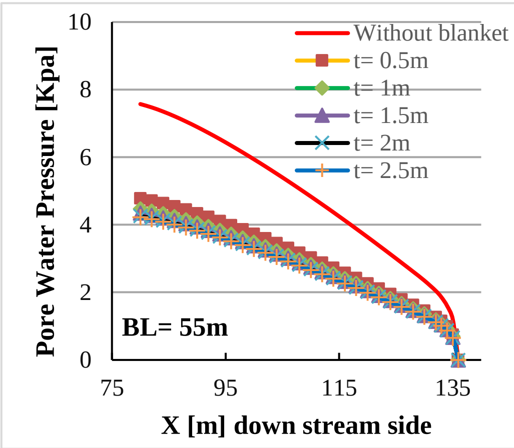
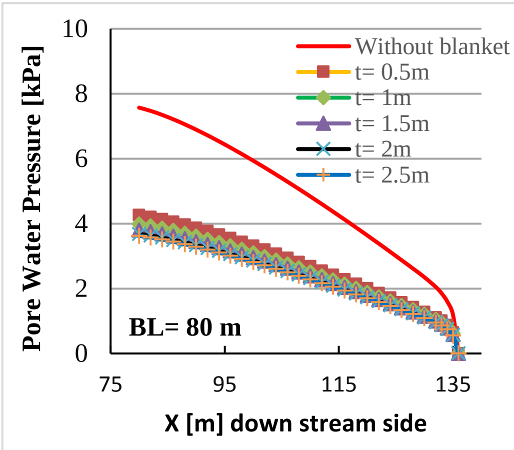


FIGURE 3. Illustrates the relationship between the percentage of (a) seepage quantity and (b) seepage reduction with various blanket thickness (t=0.5m. 1m, 1.5m, 2m, 2.5m) for three different blanket length.

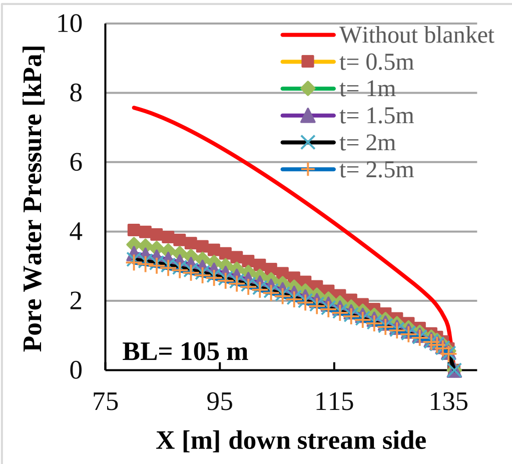
Figure 4 compares the effect of pore water pressure for the dam without and with upstream blankets with different lengths and thicknesses at the level directly under the embankment at the downstream side of the dam. It is obvious that the upstream blankets have the influence in decreasing the amount of pore water pressure. The amount of reducing of pore water pressure for the same thickness with different lengths are almost similar. This is because of existing of the filter at the downstream side of the dam. Whereas, when the lengths of the upstream blanket are increased the amount of pore water pressure slightly decrease.



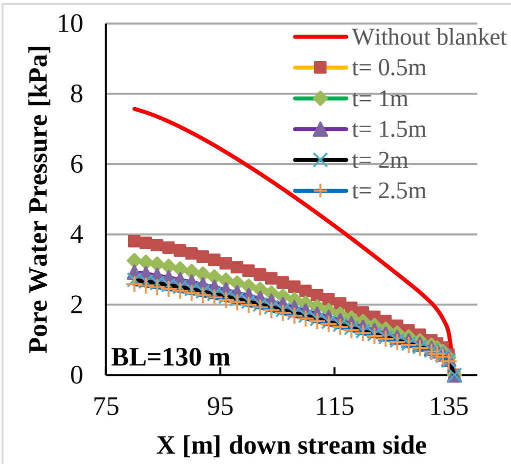
(a)



(b)



(c)



(d)

FIGURE 4. Shows the distribution of pore water pressure at the downstream side directly under the embankment due to the effects of the variation of blanket thickness and blanket length (a) BL= 55m, (b) BL= 80m, (c) BL= 105m, and (d) BL= 130 m.

Figure 5 compares the influence of pore water pressure for the dam without and with upstream blankets with different lengths and thicknesses at 4 m below under the embankment at the downstream side of the dam. It is important to note that the upstream blankets have considerable effect in decreasing the amount of pore water pressure. It is also noticeable that the differences are declined significantly from the centroid of the dam toward toe of the dam, particularly at the last 20 m. This is because there is a filter at the downstream side of the dam.

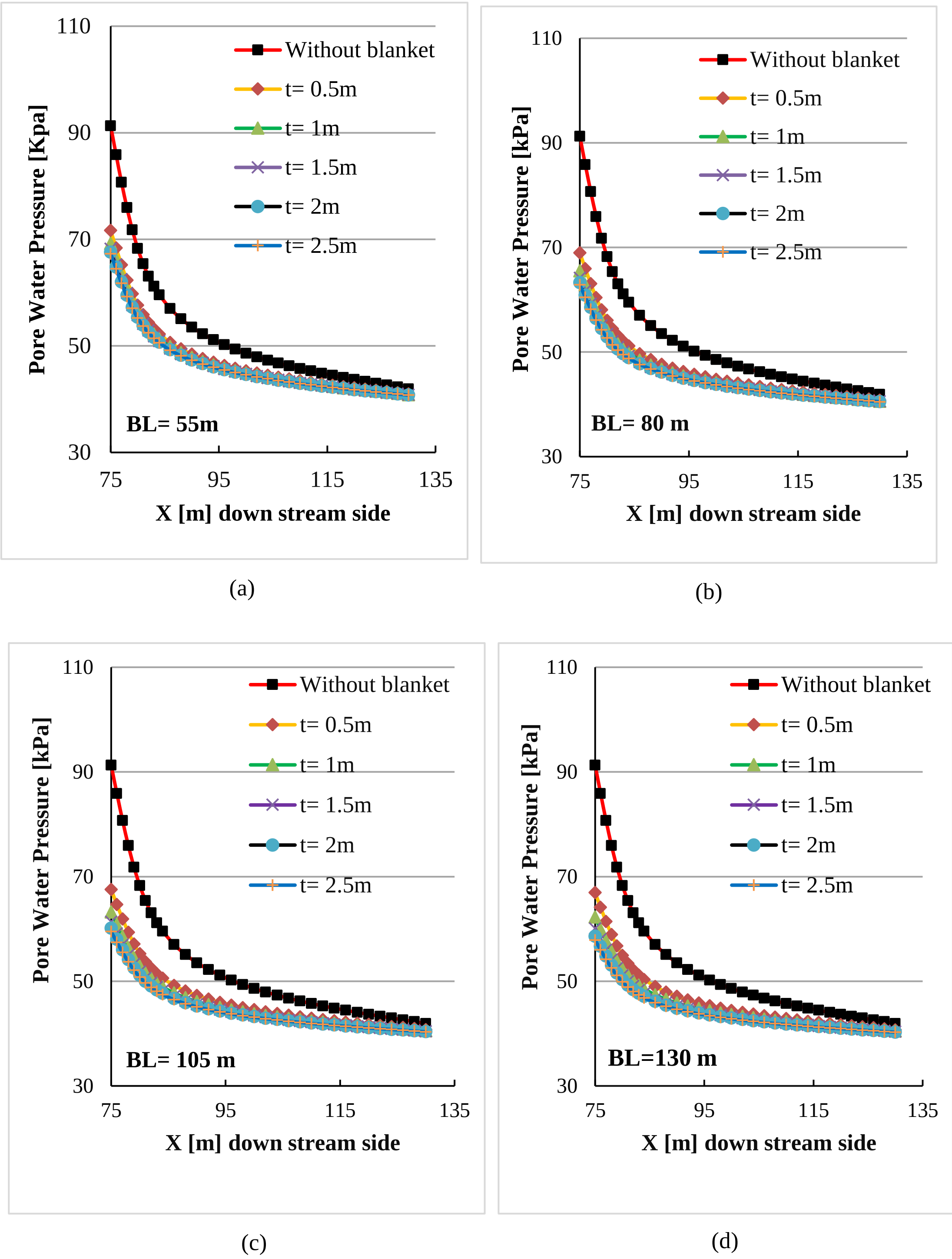


FIGURE 5. Shows the distribution of pore water pressure at the downstream side four meters under the embankment due to the effects of the variation of blanket thickness and blanket length (a) BL= 55m, (b) BL= 80m, (c) BL= 105m, and (d) BL= 130 m.

Comparing values of pore water pressure from Figure 4, with their corresponding values at the same distance in Figure 5 (i.e. at the same distance of X[m] downstream side), it is clear that the trend of reduction of the pore water pressure is substantially different. This is probably attributable to the existing of the filter at the level of 0 m (see Figure 1) and not at the level of -4 m which helps the pore water pressure to quickly reach to zero.

4. CONCLUSION

In this paper, to reduce the underseepage and pore water pressure, the effects of the upstream blanket with different lengths and thicknesses tied to the core were investigated. Based on the analyses performed of the results using SEEP/W software using the existing data, it can be concluded that the blanket length of 80 m and thickness of 1 m to 1.5 m can be recommended to be preferably utilized in a real construction. This means that the blanket length is four times greater than water head. The blanket thickness more than 1.5 m is not quite effective in the reduction of seepage and pore water pressure. The Shiwashok earth dam has not been constructed yet by the Kurdistan Regional Government (KRG) due to economic crisis. The final proposed design of the Shiwashok dam did not include a clay blanket (see Figure 1a), therefore this study recommends to add a clay blanket with the details presented in this paper, in order to increase safety and avoid possible failure to the dam.

REFERENCES

[1] D. P. Coduto, M.-C. R. Yeung, and W. A. Kitch, Geotechnical engineering : principles and practices. Upper Saddle River: Pearson, 2011.

[2] S. United, Army, and E. Corps of, Engineering and design. general design and construction considerations. [Washington, D.C.]: U.S. Army Corps of Engineers, 1994.

[3] P. Peter, "Canal and river levees. Developments of civil engineering. Vol. 29," ed: Elsevier/North-Holland, Inc., New York, 1982.

[4] James L. Sherard, Richard J. Woodward, and Stanley F. Gizienski, Earth and earth-rock dams : engineering problems of design and construction. Ann Arbor (Mich.): UMI, 1992.

[5] B. Tatone, C. Donnelly, D. Protulipac, and C. Clark, "Evaluation of the hydraulic efficiency of a newly constructed plastic concrete cut-off wall," in Proc., 2009 Canadian Dam Association Annual Conf, 2009.

[6] E. Williams, "Seepage Analysis and Control for Dams," Department of the Army US Army Corps of Engineers, Washington, 1986.

[7] M. A. E.-R. M. Rezk and A.-A. A. A. Senoon, "Analytical solution of earth dam with upstream blanket," Alexandria Engineering Journal, vol. 51, pp. 45-51, 2012/03/01/ 2012.

[8] H. Goharnejad, M. Noury, A. Noorzad, A. Shamsaie, and A. Goharnejad, "The effect of clay blanket thickness to prevent seepage in dam reservoir," Res. J. Environ. Sci. Research Journal of Environmental Sciences, vol. 4, pp. 558-565, 2010.

[9] GEO-SLOPE, Seepage Modeling with SEEP/W 2007. Calgary, Alberta, Canada: GEO-SLOPE International Ltd, 2008.

[10] USBR, Embankment Dams, Chapter 8: Seepage Washington, D.C.: U.S. Department of the Interior, Bureau of Reclamation, 2014.