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RESEARCH ARTICLE

Effect of Core Shape and its Side Slopes on Seepage Quantity of Zoned Earth Dam

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ABSTRACT

Seepage is the main problem of earth dams; most failures are occurred due to excessive amount of seepage. In zoned earth dams clay core is provided to minimize seepage quantity and its dimensions and shape has great influence on seepage quantity. In this study seepage through earth dam with vertical and slanting core case were analyzed for different side slopes and top width. For vertical core cases different side slopes ranges from 0H:1V to 2H:1V and different top width from (3-10) m were analyzed. Due to lower permeability coefficient of core material seepage discharge reduced as side slopes and top width increase. The seepage discharge for slanting core cases are more than vertical cases with similar area of core. The results obtained in this study are agreed with the results of the other investigators However, in slanting core cases the downstream part dry during steady state condition; this is helpful in improving downstream stability.

Key Words: Zoned Earth dam, Seepage, Slanting Core.

1-INTRODUCTION

Due to the availability of materials at the site and economic factors earths dams are preferred over other dam types. However, the main problem in such type of dams is excessive seepage and piping. Seepage is a loss of water through soil layers (Bayat et all, 2019). The amount of seepage in earth dams has great influence on reducing slope stability and finally failure of the dam. At zoned earth dam clay core is provided to control seepage through the body of the dam. However increasing dimensions of clay may cause reduction in seepage quantity but it causes reduction of factor of safety of dam side slopes. Schaffernak (1917) for calculation seepage through the homogeneous dam predict the flowing equation:

$$\mathbf{q = k\,l\,\sin\beta\,\tan\beta} \quad \ldots\ldots \mathbf{1}$$

$$\mathbf{l = \frac{d}{\cos\beta} - \sqrt{\frac{d^2}{\cos^2\beta} - \frac{H^2}{\sin^2\beta}}} \quad \ldots\ldots \mathbf{2}$$

Fakhari Ghanbari, 2013 predicted an equation to compute seepage discharge through the earth dam with vertical and slanting clay core. The equation for seepage estimation for vertical core are:

$$\mathbf{f = (2.27 - 0.009W - 0.00h - 0.38\tan\alpha) * H^{(-0.361)} * \left(\frac{c}{h}\right)^{(0.3947\tan\alpha + 0.015h - 1.3591)}} \quad \ldots\ldots \mathbf{3}$$

While for slanting core case the equation become:

$$\mathbf{f} = \left(\mathbf{0.4\ cot^2\lambda + 1.1cot\lambda + 0.4}\right) * \left(\frac{\mathbf{b}}{\mathbf{h}}\right)^{-(\mathbf{0.054\ cot\lambda - 0.71})}$$

$$\mathbf{b = W + H(cot\alpha - cot\beta)} \ldots\ldots\ldots.\mathbf{4}$$

Where f is seepage factor, $\boldsymbol{\lambda}$ angle inclination of core with horizontal, $\boldsymbol{\beta}$ and $\boldsymbol{\alpha}$ are angle upstream and downstream slope.

Furthermore Rezk and Senoon, 2010 developed an analytical solution to compute of seepage discharge through zoned earth dam. Niec et all, 2017compared seepage quantity through earth dam predicted by numerical modeling using Hydrus software with analytical and field studies, there is a good agreement between them. Furthermore, Jianjun & Quanshu, 2015 Analysed seepage field in earth dam with clay core using finite element software SEEP/W; they concluded that seepage changes small amount as side slope increases. Sazzad et all, 2014 provided SEEP/W to compute seepage through the body of the earth dam and compare it with analytical solution, a good agreement was found between them. Khassaf and Madhloom, 2017 studied the effect of clay core thickness and its permeability on seepage quantity using slide 5.0, it was observed that reducing core thickness increase quantity of seepage. Recently. Shape of core to factors that influences the seepage discharge and location of free surface, the wedged-shape core is the most effective in reducing seepage quantity (Kawy et all, 2021). Numerical models are widely used to evaluate seepage through earth dams. (Shakir et al, 2011), (Nayebzadeh and Mohammadi, 2011) and (Salmas et all, 2020) are used numerical tool to analyze seepage through earth dams with clay core. In the present study Slide pro is provided to investigate the effect of clay core on the seepage quantity. vertical core case with slanting core case with different side slopes was taken in this study.

2-METHODS AND MATERIALS

Degala earth fill dam was provided to analyze the effect of core side slopes and its shape on seepage discharge through the dam. The dam is zoned earth fill dam with 32 m height; its cross section is shown in figure 1. It consists of clay core, shell and a transition filter with 80 cm thickness between them, its foundation consists of two layers. The upstream slope of the dam is 1V:2.5H and downstream slope is 1V:2.75H.

In the current study, for vertical core different side slopes is provided ranges from 0H:1V to 2H:1V for slanting (inclined) core eleven cases were taken with different upstream side slope. To analyze seepage Through the earth dam Slide 6.0 is provided which is based on finite element method.

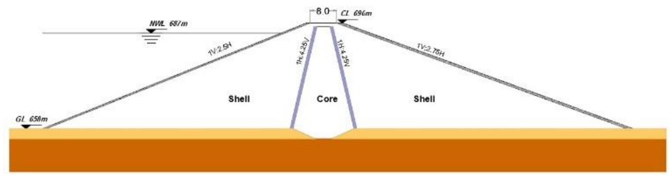

Figure 1 Cross Section of Degala Dam

3-RESULT AND DISCUSION

3-1 Validation of Results

Seepage analysis in Slide 6.0 is based on finite element method. To validate and evaluate the applicability of the software that used in this study, it compare with some methods from the literature. The seepage rate estimated by slide pro is compared with the proposed equation suggested by (Fakhari and Ghanbari, 2013) for zoned earth dam with inclined and vertical clay core and also with charts and equations suggested by (Stello, 1987). The results of seepage quantity calculated by Slide pro are close to that predicted by analytical calculations as shown in table 1. In addition the pressure head along base of the earth dam case of (Fredlund, 1993) is calculated using slide 6.0; the comparison of results is shown in figure 2. Both results are close together only some deviation at the downstream of clay core. Slice 6.0 results shows high compatibility in estimation seepage discharge and pressure head.

Table 1 seepage discharge comparison

Core Side Slope	Height of water	Height of core	K (m/s)	Seepage discharge m^3/s		
				Slide	Stello (1987)	Fakhari & Ghanbari (2013)
1V: 1H	27	28	$1*10^{-8}$	$2.4683*10^{-7}$	$1.135*10^{-7}$	$1.0898*10^{-7}$
1V:0.5H	27	28	$1*10^{-8}$	$3.6468*10^{-7}$	$1.6128*10^{-7}$	$1.1590*10^{-7}$
1V:1H	23	24	$1*10^{-7}$	$1.3042*10^{-6}$	$9.38975*10^{-7}$	$9.4432*10^{-7}$
1V:0.5H	23	24	$1*10^{-7}$	$2.4507*10^{-6}$	$1.5229*10^{-6}$	$1.0198*10^{-6}$

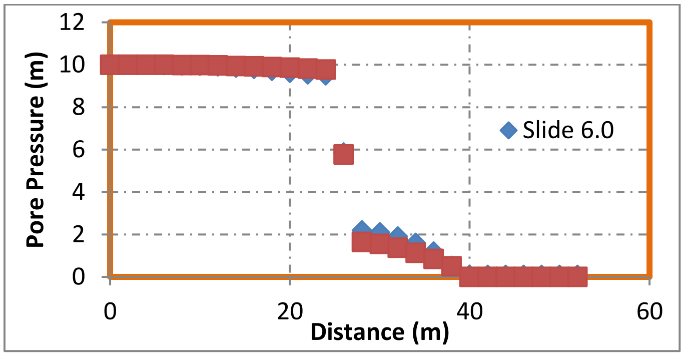

Figure 2 Comparison pressure head at the bottom of earth dam

3-2 Seepage discharge by changing side slopes and top width of core

The results of seepage quantity for different side slopes of core are shown in table (2), as can be observed as side slopes increase the seepage quantity reduced since permeability coefficient of core is much less than permeability coefficient of shell. The results of seepage quantity by increasing core top width is shown in table (3) also seepage quantity by increasing top width of core reduced. For slanting core cases the seepage quantity is estimated for different side slope the results are show in table (4). Eleven cases was taken for slanting core case, started from vertical core case and then the upstream side slope of the core was increased. Also in this case seepage discharge reduced as inclination angle increased. However if the inclination of upstream slope further increased seepage discharge will be increased.

Table 2 seepage discharge by increasing side slopes for vertical core case

Core Slope	Seepage discharge m^3/s
0H:1V	$1.2703*10^{-4}$
0.1H:1V	$8.7923*10^{-5}$
0.2H:1V	$7.0313*10^{-5}$
0.3H:1V	$6.0794*10^{-5}$
0.4H:1V	$5.4787*10^{-5}$
0.5H:1V	$5.0296*10^{-5}$
0.6H:1V	$4.7015*10^{-5}$
0.7H:1V	$4.4202*10^{-5}$
0.8H:1V	$4.177*10^{-5}$
0.9H:1V	$3.9641*10^{-5}$
1H:1V	$3.7818*10^{-5}$
1.1H:1V	$3.6059*10^{-5}$

1.2H:1V	3.4471*10^{-5}
1.4H:1V	3.1552*10^{-5}
1.6H:1V	2.898*10^{-5}
1.8H:1V	2.6592*10^{-5}
2H:1V	2.4439*10^{-5}

Table 3 seepage discharge by increasing top width for vertical core case

Core Width (m)	Seepage m^3/s
3	7.0435*10^{-5}
4	6.4146*10^{-5}
5	5.8995*10^{-5}
6	5.4563*10^{-5}
7	5.1041*10^{-5}
8	4.8048*10^{-5}
9	4.513*10^{-5}
10	4.2663*10^{-5}

Table 4 seepage discharge by increasing side slopes for slanting core case

Cases	*Seepage m^3/s*
1	1.1011*10^{-4}
2	9.205*10^{-5}
3	7.8201*10^{-5}
4	7.5872*10^{-5}
5	6.8372*10^{-5}
6	6.8887*10^{-5}
7	6.5611*10^{-5}
8	6.7811*10^{-5}
9	6.6138*10^{-5}
10	6.3435*10^{-5}
11	6.2905*10^{-5}

3-3 Comparison between vertical and slanting core

The earth dam with slanting core case is shown in figure 3. The section consists of clay core with slanting shape supported by the shell. Seepage quantity for both vertical and slanting core cases is compared fore cases with the same area of core as shown in table (5). As can be observed from results of seepage quantity vertical case has lower seepage rate than slanting case with same area of core. However slanting case is useful that make the downstream dry which is increase safety of downstream slope during steady state.

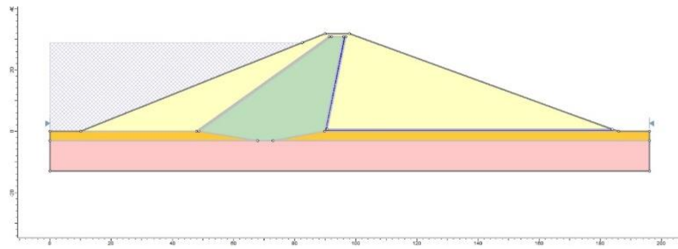

Figure 3 Geometry of the earth dam with slanting core case

Table 5 seepage discharge comparison of vertical and slanting core cases

Seepage m^3/s	
Vertical	***inclined***
8.7923*10^{-5}	9.205*10^{-5}
7.0313*10^{-5}	6.8372*10^{-5}
6.0794*10^{-5}	6.8887*10^{-5}
5.4787*10^{-5}	6.5611*10^{-5}
5.0296*10^{-5}	6.4798*10^{-5}
3.9641*10^{-5}	6.3435*10^{-5}
3.7818*10^{-5}	6.2905*10^{-5}

CONCULSION

Seepage through zoned earth dam with vertical and slanting core cases using slide 6.0. The results of slide 6.0 are verified against analytical calculations. Different side slope for both cases are provided the following conclusion were obtained.

1. By increasing side slopes and top width of core seepage discharge through the dam reduced, due to its lower permeability coefficient than shell material.
2. For slanting core case also seepage discharge reduced as upstream slope of core increase. This is related to the core area that increased

3. Compared with slanting core case, vertical core has lower seepage discharge for the same area of core.
4. Slanting core case has advantaged over vertical core, that makes the downstream part dry and increases its stability during steady state condition.

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