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Effect of Clay Blanket and Chimney Filter against Seepage Failure

MD. MAHMUD SAZZAD, MD. MAINUR RAHMAN
Department of Civil Engineering, Rajshahi University of Engineering & Technology, Bangladesh
Email: mmsruet.research@gmail.com, mainurrahmannirjhor100@gmail.com

Abstract: This paper presents the effect of clay blanket, vertical and inclined chimney filters on the phreatic line, variation of pore water pressure and seepage discharge through earth dam. Numerical analyses are conducted by SEEP/W. The results are presented for homogeneous and zoned type earth dam with clay blanket or chimney filters. Numerical results depict that earth dam with vertical and inclined chimney filter located at downstream side brings down the phreatic line within the dam body that reduces the piping and sloughing danger. Also the pore water pressure is minimum in case of downstream vertical chimney filter that reduces the possibility of blowout at downstream toe. However, the seepage discharge is greater in magnitude in case with vertical and inclined chimney filter at downstream side that increases the piping danger. In case of upstream and downstream clay blanket, seepage discharge is much lower but pore water pressure is higher than downstream vertical and inclined chimney filter and is more susceptible to blowout failure at downstream toe. Seepage discharge is found to be minimum for dam provided with internal clay core only.

Keywords: *Clay Blanket, Chimney Filter, Seepage Failure, Pore water pressure*

Introduction:

Controlled or limited uniform seepage is inevitable in all earth dams and generally, it doesn't pose any threat. However, uncontrolled or concentrated seepage through the dam body may lead to blowout, piping or sloughing at downstream toe. Recent comprehensive reviews by Foster et al. [1-2] and Fell et al. [3] show that internal erosion and piping are the main causes of failure and accidents affecting the embankment dams and the proportion of their failures by piping increased from 43% before 1950 to 54% after 1950. Zhang et al. [4] examined 593 causes of earth dam failures and discovered that 58.3% of the failures occur by piping beneath or through the earth dams. Foundation seepage pressure in pervious layers exerts an excessive force on an overlaying confining layer. Failure begins when the pore pressure on the bottom of the confining layer exceeds the overburden pressure created by the weight of overlaying soils. The resulting uplift eventually breaches or breaks throughout the confining layer which is known as a blowout, commonly forming a sand boil. Mantie [5] found that excessive pore pressures in the foundation below the embankment (created by the emplacement of embankment material) may cause heave in the foundations in front of the downstream slope. Progressive sloughing of the toe is somewhat similar to the process of piping. Progressive sloughing begins when a small amount of materials erodes at the downstream toe and produces a miniature slide. The miniature slide leaves a relatively steep face which becomes saturated by the seepage from upstream reservoir and the slides occur again. This leaves an over-steepened face which slides again forming a more unstable surface. The process continues till the portion of the dam is too thin to withstand the horizontal water pressure, leading to overtopping of the dam. Moayed et al. [6] used ABAQUS software to analyze earth dam in both steady state and drawdown condition. It was found that toe drain installation helps to lessen softening and erosion of downstream toe, but with vertical chimney filter the phreatic line tends to remain mostly in the upstream side so that seepage does not continue throughout the embankment. In rapid drawdown condition, in which the main matter is pore pressured dissipation from embankment, it is shown that the horizontal drainage blanket or toe drain has a little difference in receding the phreatic level and their performance to decrease the phreatic level don't seem to be good; hence, the chimney drain has a good capability to recede the phreatic line and decrease the pore pressure. A comparison between the numerical and analytical solution is presented and it is observed that numerical results are consistent to the analytical results [e.g. 7]. Recently, Sazzad et al. [8] studied the effect of internal clay core in the seepage control and noticed that obvious reduction of the discharge rate is observed with the addition of clay core in the model. Even though several studies were available in the literature that considered seepage failure, the study of seepage considering the clay blanket and chimney filter is rare. The objectives of this research are as follows: (i) to evaluate the effect of internal clay core, clay blanket and chimney filter on the characteristics of phreatic line through the dam body and (ii) to study effect of clay blanket and chimney filter on the pore water pressure and seepage discharge of earth-dam.

The Numerical Models:

Figures 1, 2, 3 and 4 depict the numerical models used in the present study for homogeneous earth dam, earth dam with internal clay core only, earth dam with clay blanket and earth dam with chimney filter, respectively. The dimensions are given in the figures.

Note that the vertical chimney filter is also studied although the inclined chimney filter is shown in Fig. 4 only. The numerical model is incorporated in SEEP/W and the numerical study is conducted for different conditions and positions of clay blanket and chimney filter.

Parameter used in the Study:

Earth dam model with clay blanket and chimney filter both at upstream and downstream side were considered for numerical analysis by SEEP/W [9] program (sub-program of Geo-Slope). The soil materials considered for different segments of the model is given in Table 1. The permeabilities for silty clay, clay and sand are considered to be 5.0×10^{-7} m/s, 1.0×10^{-9} m/s and 4.0×10^{-3} m/s, respectively.

Table 1: Type of material for different segments of the models

Segment	Material
Outer Soil	Silty clay
Core	Clay
Foundation	Clay
Chimney Filter	Sand
Clay Blanket	Clay

Numerical Results and Discussion:

Effect on Phreatic Line

The effect of clay core, clay blanket and chimney filter on the evolution of phreatic line is depicted in Figs. 5 to 7. In case of homogeneous type dam, phreatic line crosses downstream face of the dam, which in not desirable. Provision of an internal clay core reduces this phenomena and brings down the phreatic line within the dam body as shown in Fig. 5. Provision of clay blanket both at the upstream and downstream side is not sufficient enough to bring down the phreatic line within the dam body developing undesirable condition as shown in Fig. 6. Due to provision of vertical and inclined chimney filter at upstream position, phreatic line crosses downstream face in both cases. If the filters are positioned in downstream side, phreatic line lies within the dam body in both cases, as shown in Fig. 7.

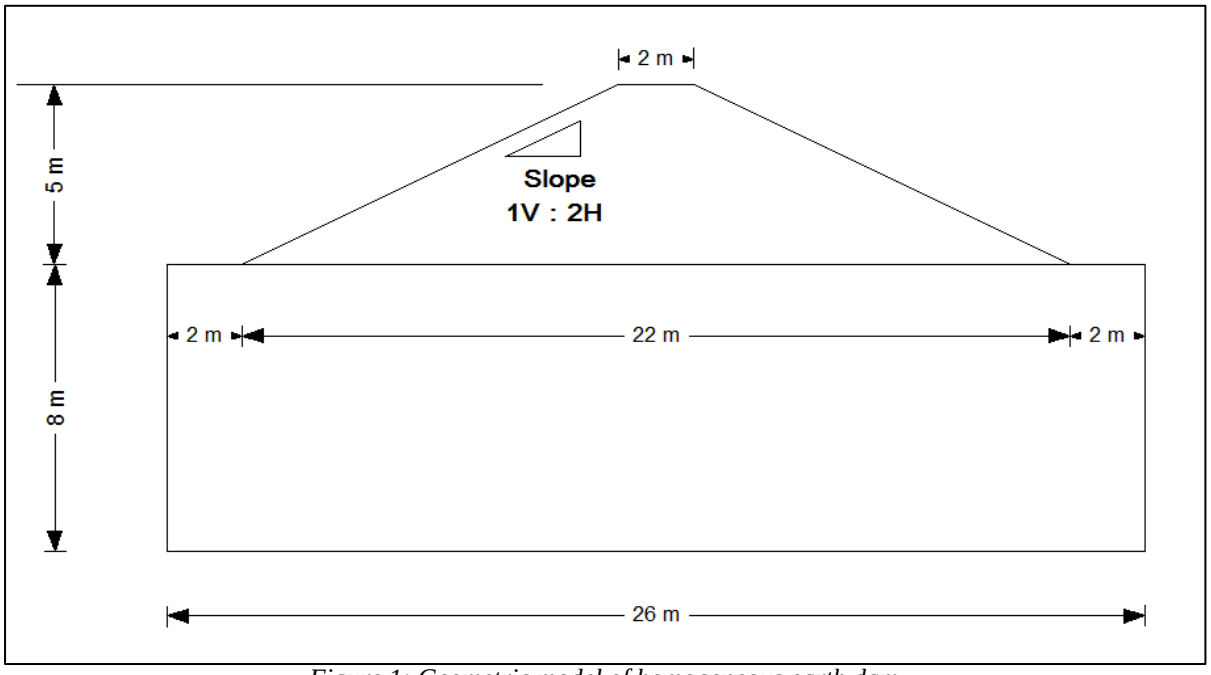


Figure 1: Geometric model of homogeneous earth dam

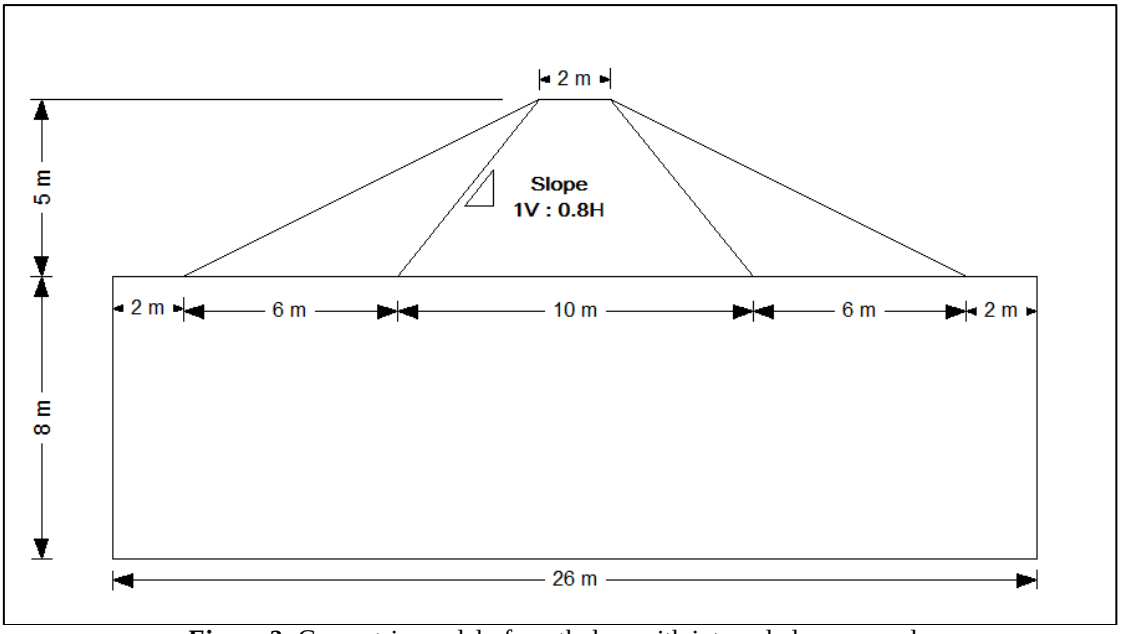


Figure 2: Geometric model of earth dam with internal clay core only

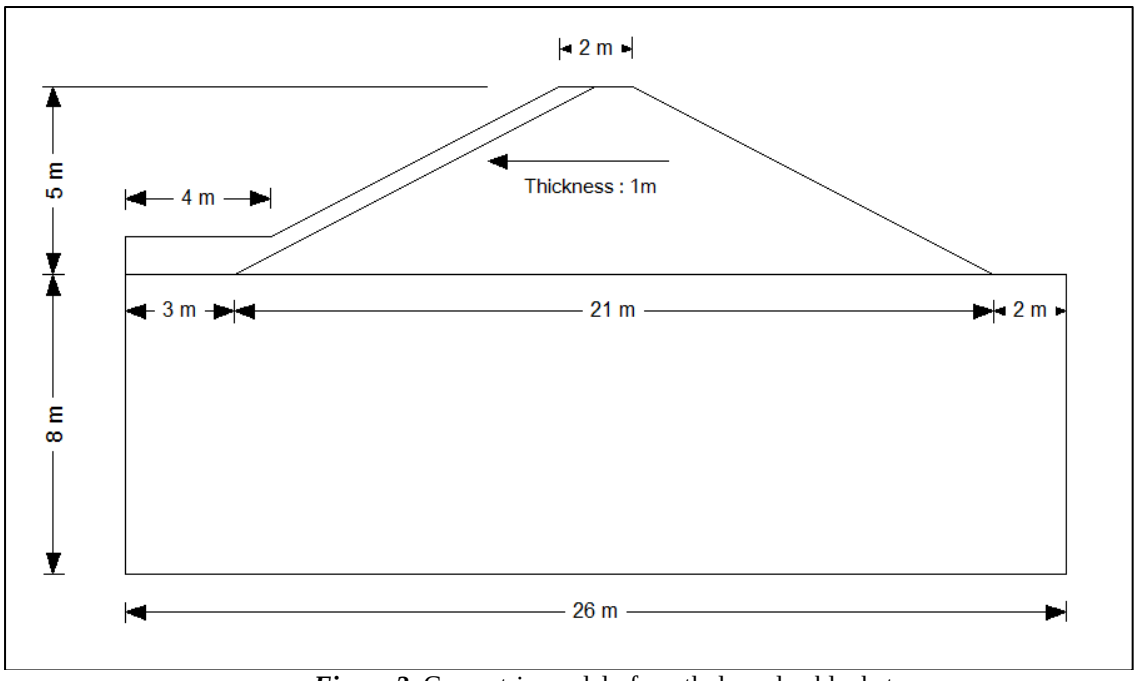


Figure 3: Geometric model of earth dam clay blanket

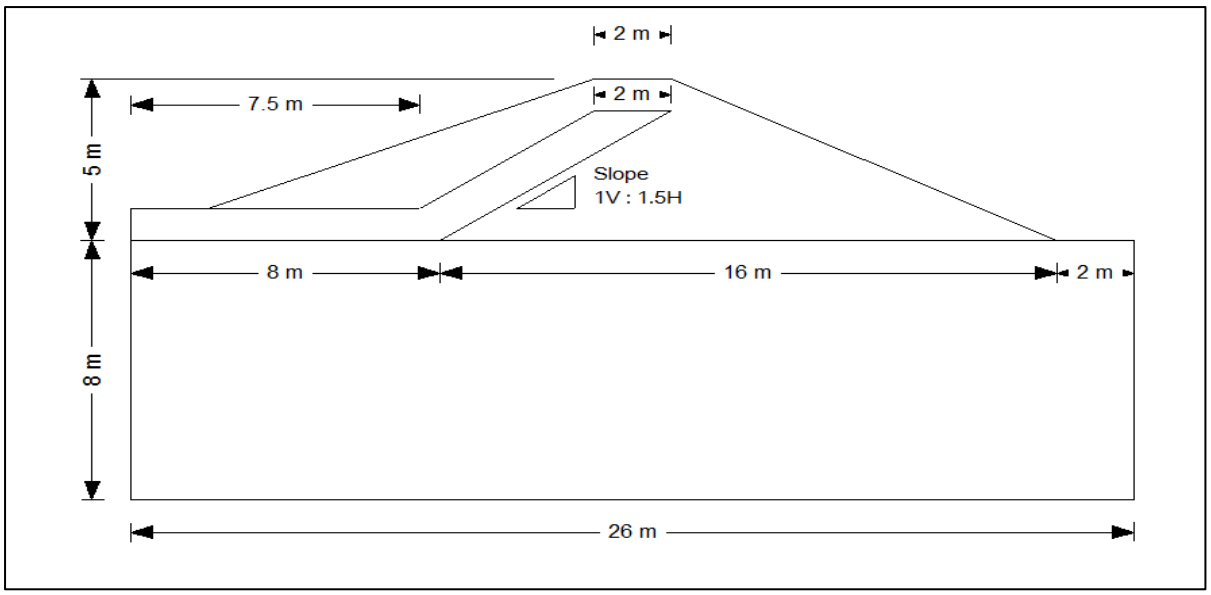
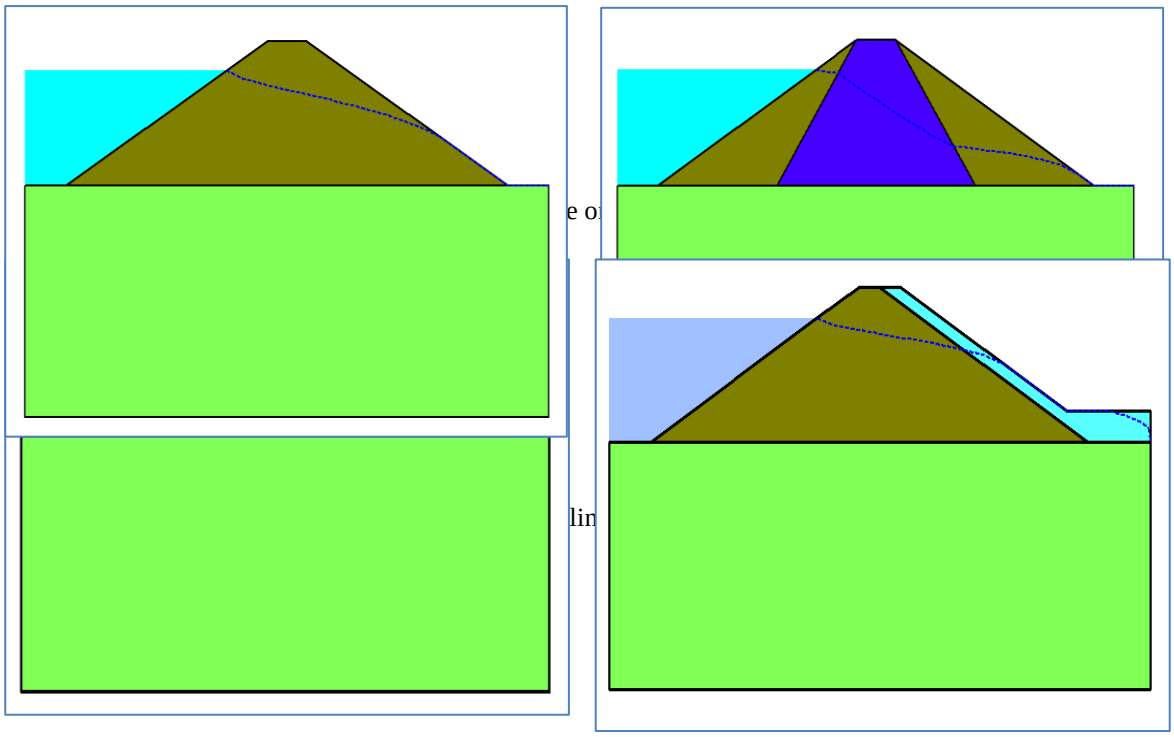


Figure 4: Geometric model with inclined chimney filter

Effect on Pore Water Pressure

The effect of clay core, clay blanket and chimney filter on the evolution of pore water pressure is depicted in Fig. 8. Provision of clay blanket at upstream side reduces the pore water pressure with respect to homogeneous type dam but still greater in magnitude than zoned type beyond middle point of dam. As for downstream position of vertical and inclined chimney, magnitude of pore water pressure is reduced with respect to both homogeneous and zoned type of dam as shown in Fig. 8. Note that the maximum reduction of the pore water pressure is achieved when the downstream vertical chimney filter is incorporated in the numerical model and thus it depicts the application of downstream vertical chimney filter in reducing the pore water pressure. Note also that chimney filter proves to be an effective measure to bring the phreatic line down in the dam body and to reduce the pore water pressure at the middle point of dam compared to the clay blanket. The use of internal clay core is also effective compared to the clay blanket.



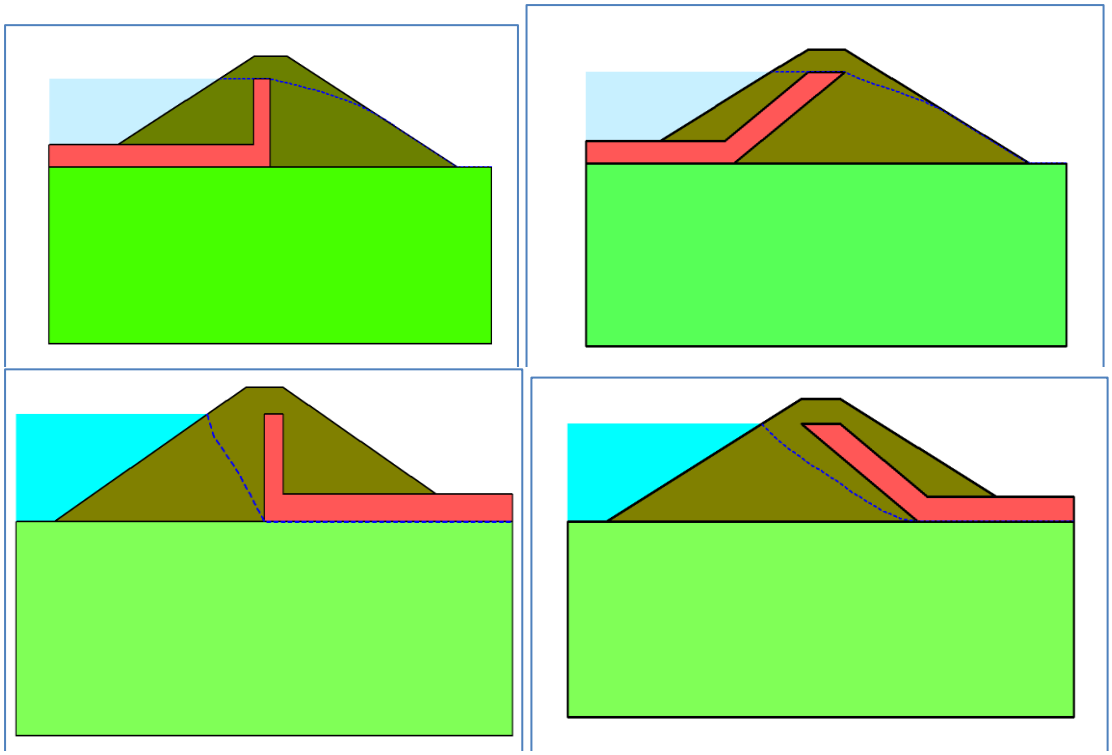


Figure 7: Effect on phreatic line due to provision of chimney filter at upstream and downstream side

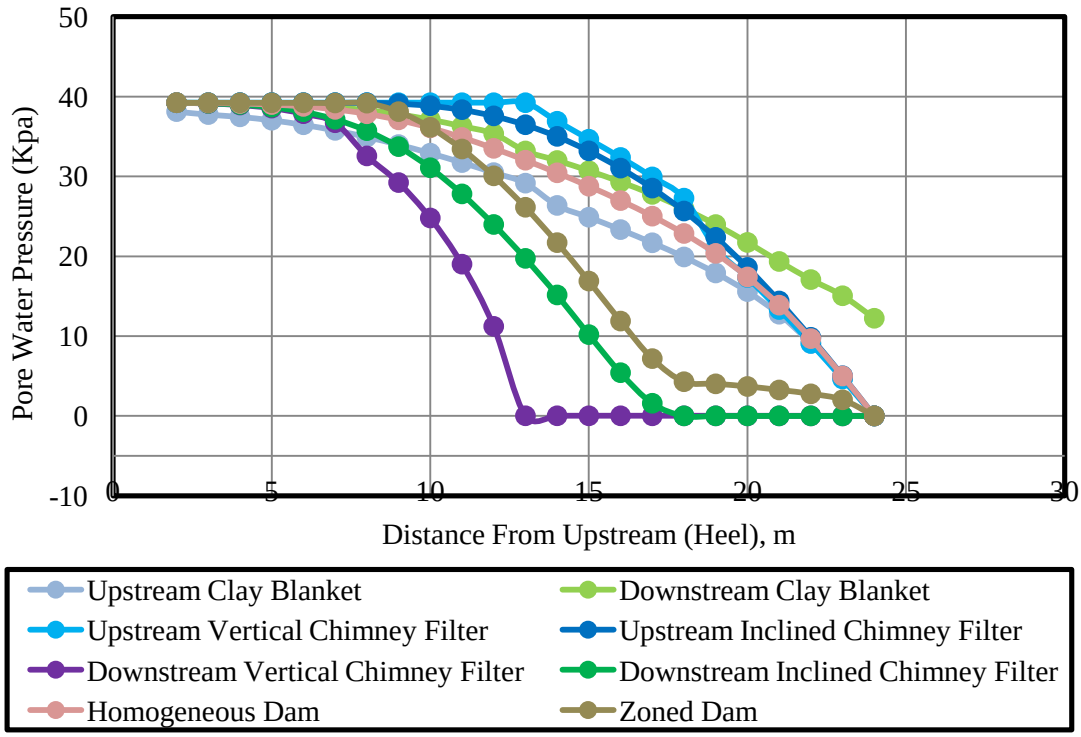


Figure 8: Effect on pore water pressure for homogeneous dam, zoned dam, upstream and downstream clay blanket, vertical and inclined chimney filter

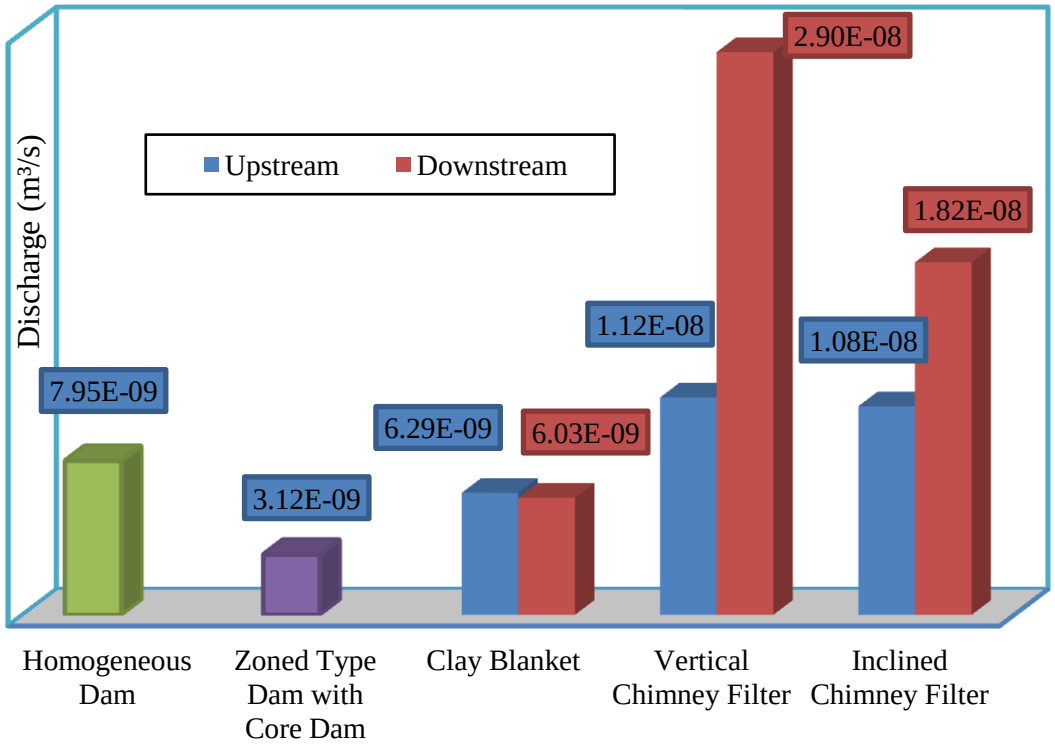


Figure 9: Effect on discharge pressure for homogeneous dam, zoned dam, upstream and downstream clay blanket, vertical and inclined chimney filter

4.3 Effect on Discharge

The effect of clay core, clay blanket and chimney filter on the seepage discharge is depicted in Fig. 9. The lowest discharge is obtained when zoned type dam with internal clay core is considered. Indeed the use of clay blanket reduces the discharge through the earth dam, but it cannot reduce the discharge as much as a zoned type dam with clay core can. However, it can be concluded that clay blanket is also an effective measure in reducing the seepage discharge through the earth dam. By contrast, the use of vertical chimney filter is not an effective measure to reduce the seepage discharge.

5. Conclusion

In this study, Numerical analysis has been performed to study the effect of internal clay core, clay blanket and chimney filter on the position of phreatic line, seepage discharge and pore water pressure. Some of the important points of the study are summarized as follows:

(i) Provision of chimney filter at downstream side brings down the phreatic line within the dam body, thus it reduces sloughing danger to dam.

(ii) Pore water pressure is minimum in case of downstream vertical and inclined chimney filter but seepage discharge is much higher than that of clay blanket and zoned type dam with core which increases piping danger.

(iii) In case of upstream inclined and vertical chimney filter, pore water pressure is larger than that of downstream position and clay blanket which may blow out the downstream toe.

(iv) Pore water pressure is higher in case of upstream and downstream clay blanket but seepage discharge is the lowest of all. Also the phreatic line cuts the dam at downstream side in both cases which reduce the piping danger to a great extent but increases sloughing danger.

05. Dam provided with vertical chimney filter at downstream side is more suitable for construction.

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