SEEPAGE ANALYSIS OF MATATILA DAM USING SLIDE SOFTWARE

A DISSERTATION

SUBMITTED IN PARTIAL FULFILLMENT OF THE REQUIREMENTS
FOR THE AWARD OF THE DEGREE
OF

MASTER OF TECHNOLOGY
In
HYDRAULICS AND WATER RESOURCE ENGINEERING

Submitted by
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CANDIDATE'S DECLARATION

I, **MADHUR KUMAR SINGH**, Roll No. **2k18/HFE/08** of **M.Tech (HWRE)**, hereby declare that the project Dissertation titled "**seepage analysis of matatila dam using slide software**" which is submitted by me to the department Hydraulics and Water Resource Engineering, Delhi Technological University, Delhi in partial fulfilment of the requirement for the award of the degree of Master of Technology, is original and not copied from any source without proper citation. This work has not previously formed the basis for any Degree, Diploma Associateship, Fellowship or other similar title or recognition.

Place: Delhi   Madhur Kumar Singh

Date:

Hydraulics and Water Resource Engineering
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CERTIFICATE

I hereby certify that the project Dissertation titled "**Seepage analysis of Matatila dam using Slide Software"** which is submitted by **MADHUR KUMAR SINGH,** Roll number **2k18/HFE/08** of M.Tech (**HWRE**), Delhi Technological University, Delhi in partial fulfilment of the requirement for the award of the degree of Master of Technology, is record of the project work carried out by the students under my supervision. To the best of my knowledge this work has not been submitted in part or fully for any Degree or Diploma to this University or elsewhere.

Place: Delhi

Date:

Dr. **MUNENDRA KUMAR**
(Professor)
Department of Civil Engineering
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ACKNOWLEDGEMENT

I take this opportunity to express my sincere regards and deep gratitude to **Dr. Munendra Kumar** (professor, civil engineering department, DTU) for his consistent guidance, monitoring and constant encouragement throughout the course of this project work. Also, I express my gratitude to **Department of Civil Engineering, DTU** for giving me such an opportunity to commence this project in the first instance.

Professors and faculties of the civil engineering department, DTU have always been very supportive and cooperative. They have been always present for their kind opinions and suggestions regarding this project work and therefore I am deeply obliged to them.

Last but not the least, I would like to thank my family and my colleagues from the department who encouraged me to bring this work to a successful close.

ABSTRACT

Seepage pressure is one of the most important factor that affects the stability of embankment dams. In this study a detailed seepage analysis on Matatila dam, Lalitpur(Uttar Pradesh) is done with the help of Slide software. Seepage discharge through homogenous earthen dam, zoned earthen dam and homogenous earthen dam with a cutoff wall is calculated and a comparison is made among them. It was observed that the zoned earthen dam yields better results when a comparison is made with homogenous earthen dam with a cutoff wall for seepage reduction through downstream sloping face and foundation of the dam. Variation of various parameters such as total head, pressure head, pore pressure, horizontal discharge velocity, vertical discharge velocity, horizontal hydraulic gradient, horizontal permeability and vertical permeability are also shown with the help of figures in the results section.

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CHAPTER-1

INTRODUCTION

1.1 GENERAL

Earthen dams are water impounding bodies which consist of natural materials (such as soil and rock). These materials acquire their strength from internal friction and cohesion between the particles, unlike gravity dams which gains the stability from self-weight itself.

In ancient times these dams used to form naturally by the effect of landslide and rockfalls, which by cutting off streams, resulting in the formation of natural dams. A 300 m natural dam was found on the upper reaches of river indus. But having composition of loose materials, this dam failed causing a great damage to lives and property in Indus valley. Till 1925, height of earthen dams rarely exceed 30m but due to advancement of soil mechanics, it is now possible to design higher earthen dams with much reliability. Some examples are Beas dam (115m) and Ramganga (125m) in India, Oroville dam (224m) in USA, Greek dam(235m) in Canada and Nurek dam (300 m) in USSR.

Earthen dams are mainly divided in two parts :

(1) Earth-fill or earthen dams

(2) Rock-fill or earth rock dams.

The earth fill dams mainly consists of soil while rock fill dams have rock material as major composition, but design principle is similar for both the dams.

Earth dams further classified into following types:

(1) homogenous earth dam,

(2) zoned earth dam.

Homogenous earth dams are constructed of almost one type of material. Homogenous earth dam of height exceeding 8 m is provided drain of material more pervious than embankment soil. Such drain decreases pore water pressure in downward portion of the dam resulting in increase in dam's stability. Apart from this drains control outgoing seeping water in such a manner it does not lead to piping.

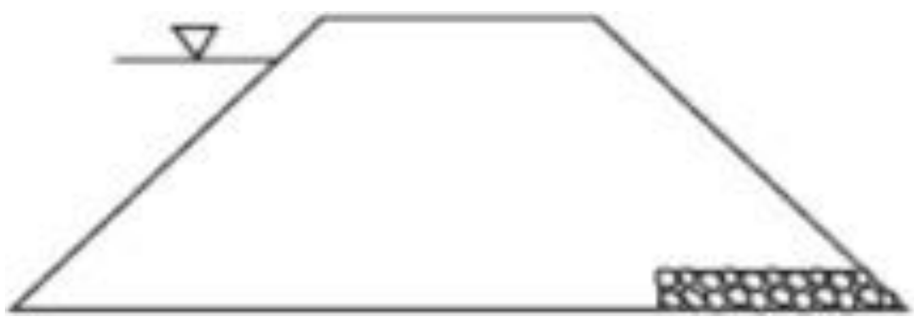

Figure 1-homogenous earthen dam

However a zoned earthen dam consists of different materials in the different parts of the embankment. It is most common type of earthen dam adopted because it leads to an economic and stable design. There is a central impervious core surrounded by zones of more pervious materials.

These zones are called as shells which supports and protect the impervious core. Upstream shell provides stability against rapid drawdowns of reservoir while the downstream shell acting as drain to control the line of seepage and provides stability to dam during its construction.

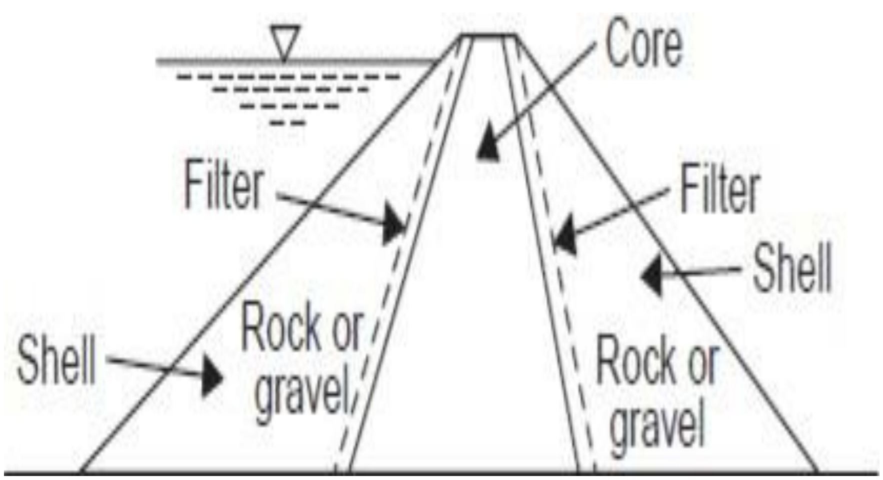

Figure 2-zoned earthen dam

A rock fill dam is an embankment using large size rock pieces to provide stability and an impervious layer to provide water tightness. The membrane is made up of materials like earth, concrete, steel, steel, asphalt and wood.

The impervious membrane is generally placed on the upstream face of the dam because it prevents seepage entering the embankment resulting in the greater stability of the embankment. Also apart from this upstream impervious membrane is accessible for the inspection and repair.

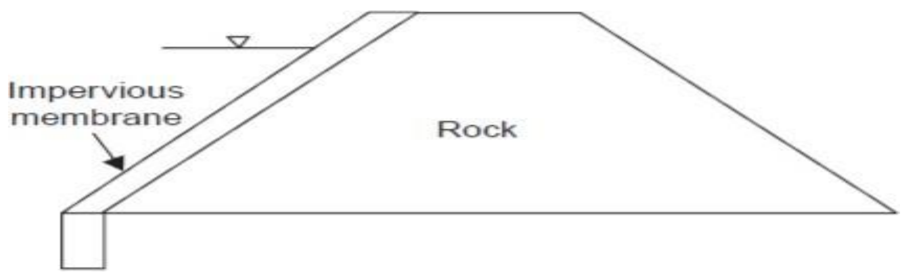

Figure 3- A rock fill dam

1.2 ESTIMATION AND CONTROL OF SEEPAGE

Theory of flow in porous media is used for the estimation of seepage through the embankment dam and its foundation. Laplace equation is used for the two-dimensional seepage occurring in embankment dam and its foundation which is given below;

$$\frac{\partial^2 h}{\partial x^2} + \frac{\partial^2 h}{\partial y^2} = 0$$

Where h= seepage head

The above equation is only valid for the homogeneous, isotropic and incompressible soil. Seepage problems relating to the embankment dams can be analyse by drawing flownets for the sections with single permeability. For instance, if outer zones of the dam are more permeable than the core, the analysis of seepage conditions in core alone are sufficient for such cases. But in many seepage problems we have to analyse seepage through zones of different permeabilities. For these type of condition, soil of one permeability is passed to a soil of other permeability. Seepage water requires less energy to flow through a relative higher permeability region. So when water flow from a higher to lower permeability region, the flow took place in such a way that it will be in a region of more permeability for the greatest distance. Alter,we can say that in order to conserve its potential, water finds the easiest to travel.

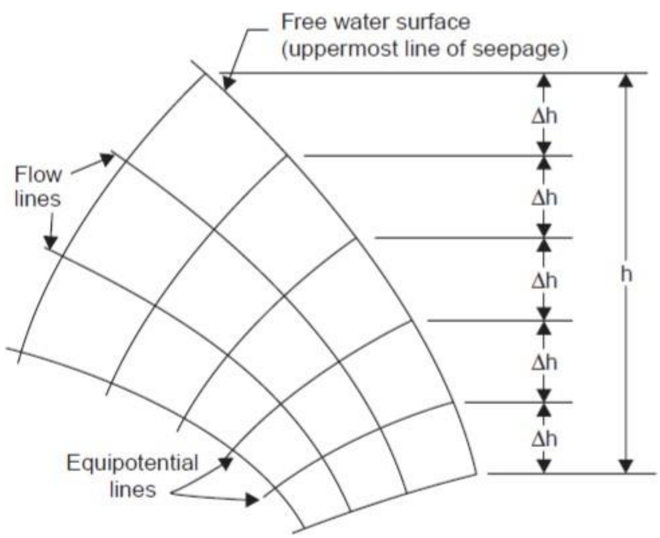

Fig 4- general lines for the lines of seepage

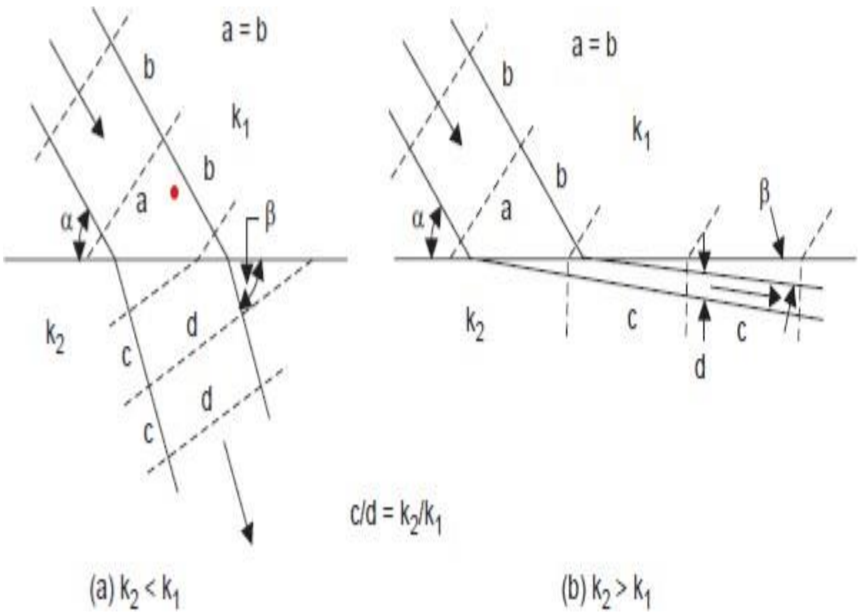

Fig 5- change in shape of flownet squares on account of regions of different permeability.

The above fig. shows deviation of flow lines when they crosses boundaries between soil of different permeabilities. The flow lines follows the following pattern that is given below;

$$\frac{\tan\beta}{\tan\alpha} = \frac{k1}{k2}$$

1.3 AIM AND OBJECTIVE OF PRESENT WORK

The objective of my work are as follows;

1. to reduce seepage discharge through the Matatila dam, Lalitpur (Uttar Pradesh) through various methods like using cutoff wall inside the foundation, using zoned embankment by using Slide software.
2. the results obtained from these conditions are compared with the homogenous embankment and percentage seepage discharge reduction is calculated in both the cases.
3. To compute the variation in various other parameters like horizontal discharge velocity, vertical discharge velocity, total head, pore pressure, horizontal permeability, vertical permeability and horizontal hydraulic gradient.

CHAPTER 2

LITERATURE REVIEW

1. TITLE- Experimental investigation of piping potential in earthen structures.
AUTHOR- Kenin S. Richards, Krishna R Reddy
YEAR- 2008
DESCRIPTION- A series of laboratory experiments were conducted to assess piping potential.

A true triaxial load cell was established and used for the testing. The load cell was designed to provide the flexibility to modify the loading conditions among three orthogonal axes and to permit loading the cell with pressurized water. the parameters investigated with respect to pipe initiation are as follows-

a) pipe initiation behaviour under variable stress tensor;
b) effect of exit geometry on piping potential
c) effect of load path on piping potential
d) pipe initiation behaviour under variable seepage stress rates.

Pilot test results confirm that there is an energy element in pipe initiation that presently is not passably considered in piping assessments and that the exit velocity is a better analyst of piping potential than the hydraulic gradient. Hydraulic exit losses were found to play a important role in pipe beginning. The critical hydraulic gradients resolute in these horizontal flow tests are lower than standard theory would predict. A weak relationship between confining stresses and critical hydraulic gradients was observe at high confining stresses.

2. TITLE- Seepage Analysis of an Embankment
AUTHOR- Arun K. Chopra , Dr. S K Ukarande
YEAR- 2018
DESCRIPTION- One of the most important causes that affects the stability of an embankment is seepage pressure. The graphical properties of a flow net are used to obtain the keys to many seepage problems such as evaluation of seepage through an embankment, examining the possibility of piping under dams and determination of uplift pressures below dams etc. To construct a flow net, the first step is to determine the location and shape of the phreatic line or the top flow line. In this study, an attempt is made to develop the new methods for construction of a top flow line. For this resolution, equation of cubic parabola and Laplace’s equation are used. More, using Laplace’s equation, a closed-form solution is derived to find the potential at various points in seepage zone of an embankment.

3. TITLE- Comparative and Numerical Analyses of Response of Concrete Cutoff Walls of Earthen Dam on Alluvium Foundation
AUTHOR- Lifeng Wen, Junrui Chai, Zengguang Xu, Yuan Qin, and Yanlong Li
YEAR-2015
DESCRIPTION- Though a number of cutoff walls have built in dams having alluvial foundations, the produced wall response still requires more understanding. comparative study of responses of cutoff walls on the basis of comparative analysis and numerical simulation is done by this paper. The study first collected a database of 58 cases illustrating the performance of concrete cutoff wall. The loading attributes, typical deformation pattern , deformation response of the walls installed at different locations were reviewed from a comparative point of view based on case histories. The effects of quite a few factors on the wall response have discussed. A three-dimensional finite-element deformation analysis conducted to provide further understanding of the response of cutoff walls and mechanisms that alter their response. The mechanical response, damage distribution, and crack up of the concrete cutoff wall located in the upstream face of the dam were examined and compared with those of walls located at the middle of the base of the dam fill. The numerical results for the mechanical responses of the wall also matched with the in-situ measurements and comparative results to verify validity of the numerical model.

4.TITLE- Simulation of Piping in Earth Dams Due to Concentrated Leak Erosion
AUTHOR- Tianhua Xu and Limin Zhang
YEAR- 2013
DESCRIPTION- One of the most important causes of dam failure is piping. Concentrated leak erosion occurring in cracks or a system of interconnecting voids, responsible for a large percentage of dam failures. A physically-based numerical model for simulating piping in earth dams due to concentrated leak erosion is developed in this study. The development of piping includes surface erosion and collapses of soils on the pipe wall, which is regulated by hydraulic conditions and soil properties. The outflow hydrograph and piping characteristics can be forecasted using this model, which helps to evaluate the flood hazard downstream. The failure of Teton Dam in Idaho, USA is simulated using this model. The simulation results approximately reproduce the piping failure process of the dam.

5.TITLE- Boundary Condition of Groundwater Flow through Sloping Seepage Face
AUTHOR- Kazumasa Mizumural and Tsubasa Kaneda
YEAR- 2010

DESCRIPTION- The downstream boundary condition of unconfined groundwater flow through the trapezoidal aquifers of which upstream end is vertical and downstream seepage face is sloping has been experimentally and theoretically evaluated by this paper. Hele-Shaw model is used to experimentally simulate flow through the trapezoidal aquifer. The upstream end is impervious and the downstream boundary forms a drawdown flow on a sloping seepage face. The drawdown flow is shaped on a seepage face when hydraulic gradient at a seepage point is less than seepage face slope. Discharge through the sloping seepage face is seen to be proportional to fluid depth at the seepage point, where a phreatic surface crosses the seepage face. When the angle of the seepage face to horizontal is between 45 and 90°, the hydraulic gradient at the seepage point is found to be 1/2. This is independent of the seepage face slope. When the angle of the seepage face to horizontal is less than 45°, the phreatic surface crosses the seepage face. The theoretical result of the downstream boundary condition is found to be in good contract with the experimental data.

6. TITLE- Seepage through rockfill dams in narrow valleys.

AUTHOR- Ali Soleimanbeigi; and Fardin Jafarzadeh

YEAR- 2008

DESCRIPTION – One of the most important stages in design of embankment dam is seepage analysis. A little attention is paid to seepage through abutments in two-dimensional seepage analysis of earthen dams. Two and three-dimensional models of an earthen dam while operating state are presented in this paper. Also in addition to this, several unsteady and steady state seepage analysis are done using finite element method. The results produced were compared with measurements from instrumentation system available in the dam body and foundation while construction. Also, several graphs were developed to find 3D discharge rate and hydraulic gradients from those which were obtained from 2D seepage analysis.

CHAPTER-3

METHODOLOGY

3.1 GENERAL

Matatila dam which is an earthen dam situated in, Lalitpur, Uttar Pradesh. This dam is built on the Betwa river. Betwa river is a major tributary of river Yamuna originating from Raisen district of Madhya Pradesh and it finally meets to Yamuna at Hamirpur district of Uttar Pradesh.

It mainly flows in the Bundelkhand region covering a total drainage area of about 44000 kilometers square of which 68% lies in Madhya Pradesh and remaining 32% in Uttar Pradesh.

Fig. 6 – Matatila dam at a glance

3.2 SALIENT FEATURES OF DAM

Data is collected from irrigation department, Uttar Pradesh which is as follows;

- Name of the project- Matatila Dam
- Location- Lalitpur
- Objective- Irrigation, hydropower and water supply
- Source of supply- Betwa River
- Catchment Area- 20720 Sq. km
- Average rainfall- 1140 mm
- Maximum flood discharge- 23390 Cumecs.
- Year of Start- 1952
- Year of Completion- 1964
- Dam type- earthen
- Maximum height of dam- 45.72 m
- Length =6300m
- Non over flow- 247.20 m
- Spillway - 490 m
- Earth dam- 5563 m
- Type of gates- vertical
- No. of gates – 23
- Design flood discharge- 15857 Cumecs.
- Submerged area at F.R.L- 13855 ha
- Gross storage capacity- 1132.68 M Cum.
- Live Storage- 754.60 M Cum.
- Installed capacity- 30.6 MW

3.3PROCEDURE

1. First of all , the dam is assumed homogenous i.e made up of only one type of filler material, filler material medium grained sand is used having permeability K = 1 $\times 10^{-5}$ m/sec (average values of permeability is used due to unavailability of data).
2. Free board of 2 m is provided so that head is reduced to 43 m instead of 45.
3. A horizontal scale of 1 in 50 is used to plot the data efficiently.
4. Foundation depth is assumed to be 10 meters.
5. Slide software is used to run the data and discharge seeping through the foundation and downstream sloping face is calculated.
6. Additional parameters like horizontal discharge velocity, horizontal hydraulic gradient, pore pressure, total head, vertical discharge velocity, horizontal permeability and vertical permeability are also represented with the help of diagrams shown in result section.
7. Similarly now zoned type earthen dam is analyzed having a core made up of clay having permeability ; K= 1×10^{-10} m/sec .
8. Same steps are repeated with homogenous dam with a cutoff wall of same permeability as that of core of the dam.
9. Relative comparison is made among all the three cases and seepage reduction through foundation and downstream sloping face is calculated and compared with each other.
10. All the results are presented in results section.

ABOUT THE SLIDE SOFTWARE

Slide is the most efficient slope stability analysis software available, complete with finite element ground water seepage analysis, rapid drawdown, sensitivity and probabilistic analysis and support design. All types of soil and rock slopes, embankments, earth dams and retaining walls can be analyzed.

Slide is the only slope stability software with built-in finite element groundwater seepage analysis for steady state or transient conditions. Flow, pressures and gradients are calculated based on user defined hydraulic boundary conditions. Seepage analysis is fully integrated with the slope stability analysis or can be used as a standalone module.

CHAPTER 4

RESULT AND DISCUSSION

4.1 CASE 1- When earthen dam is considered homogenous ie without any core wall BASIC VIEW

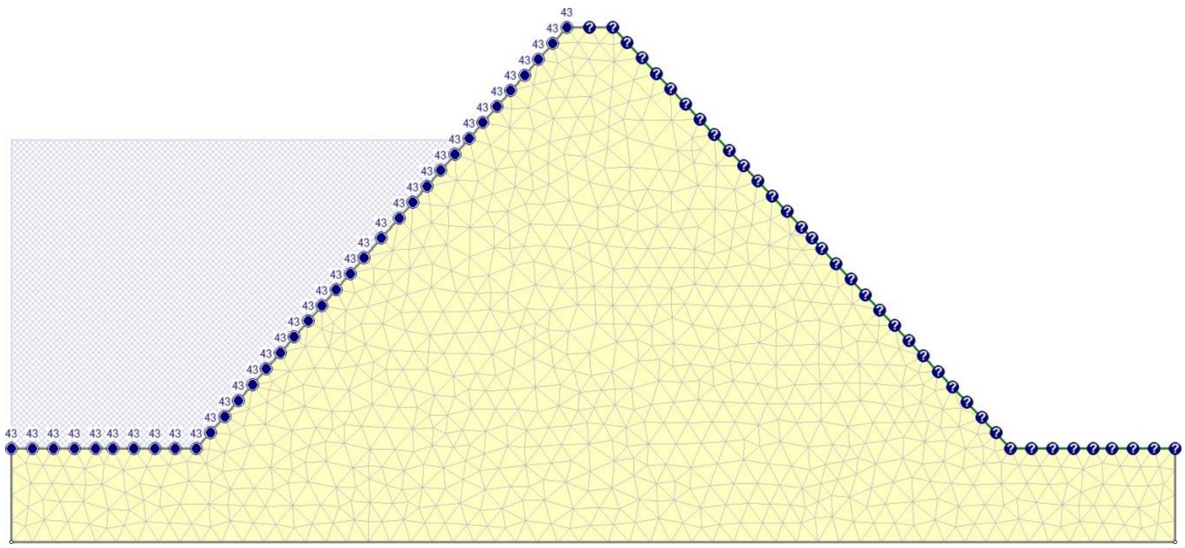

Figure 7- section of homogenous earthen dam

- Water table is applied upto a height of 43 meters, a freeboard of 2 m is provided.
- Filler material is medium grained sand

$K = 1 \times 10^{-5}$ m/sec

Total length of dam =6300 m

The discharge section is downstream sloping face as well as foundation.

Length of discharge section= 80.014 m

Width of crest = 5m

INTERPRETED VIEW

1. Variation of total head

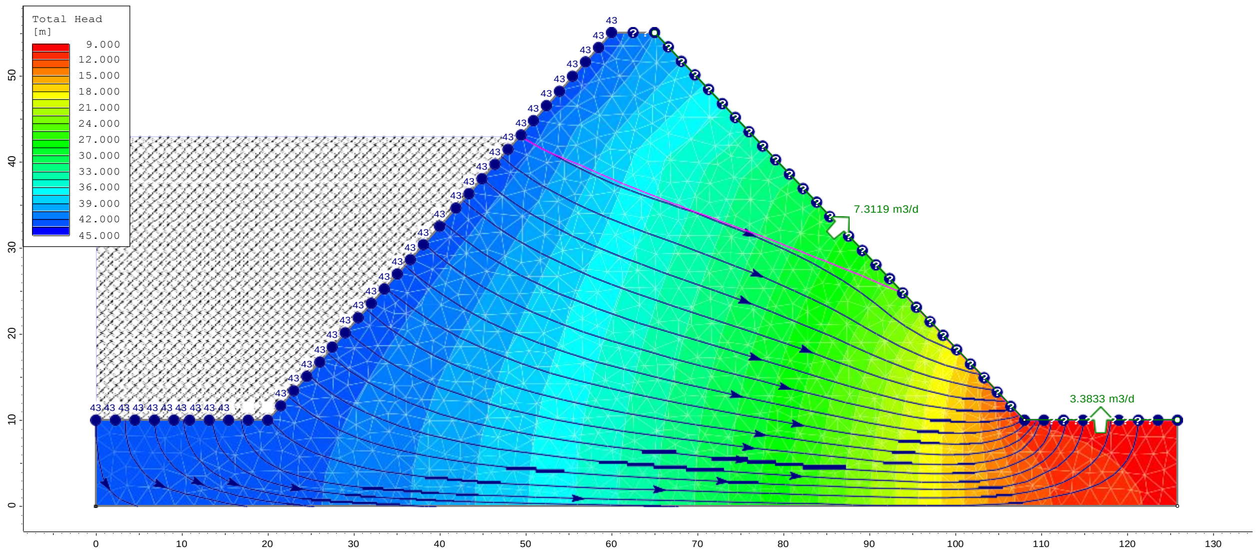

Figure 8-variation in total head in homogenous earthen dam

Discharge seeping from the downstream sloping face= 7.3119 m^3/day
Discharge seeping from the foundation in downstream face=3.3833 m^3/day

- 20 Flowlines are shown in above diagram.
- Topmost flowline is called as phreatic line

2- variation in pressure head

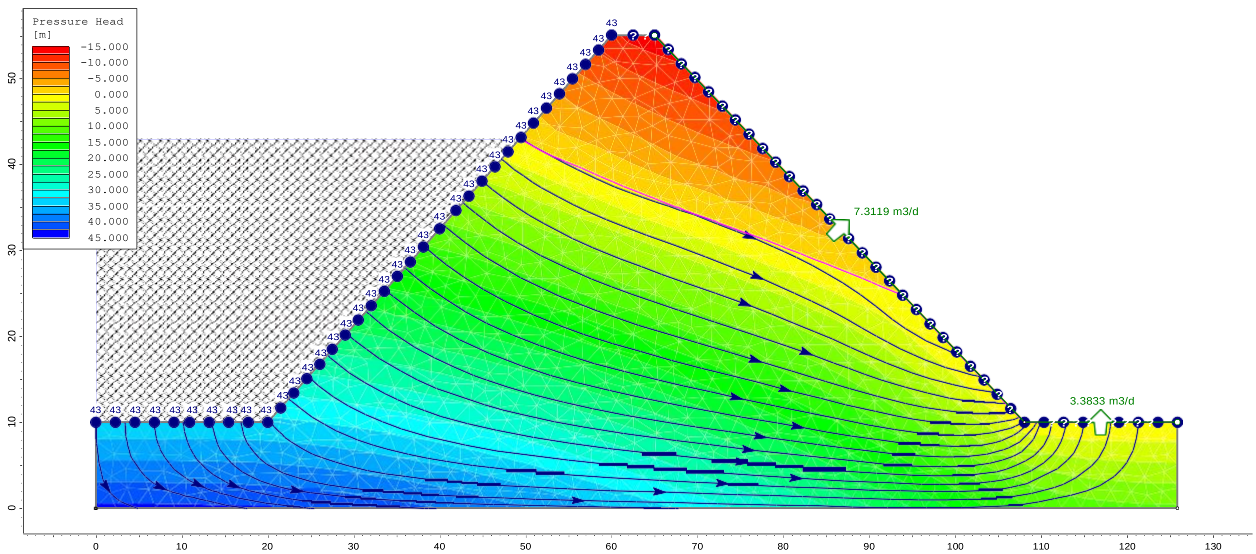

Figure 9- variation in pressure head

3. Variation in pore pressure

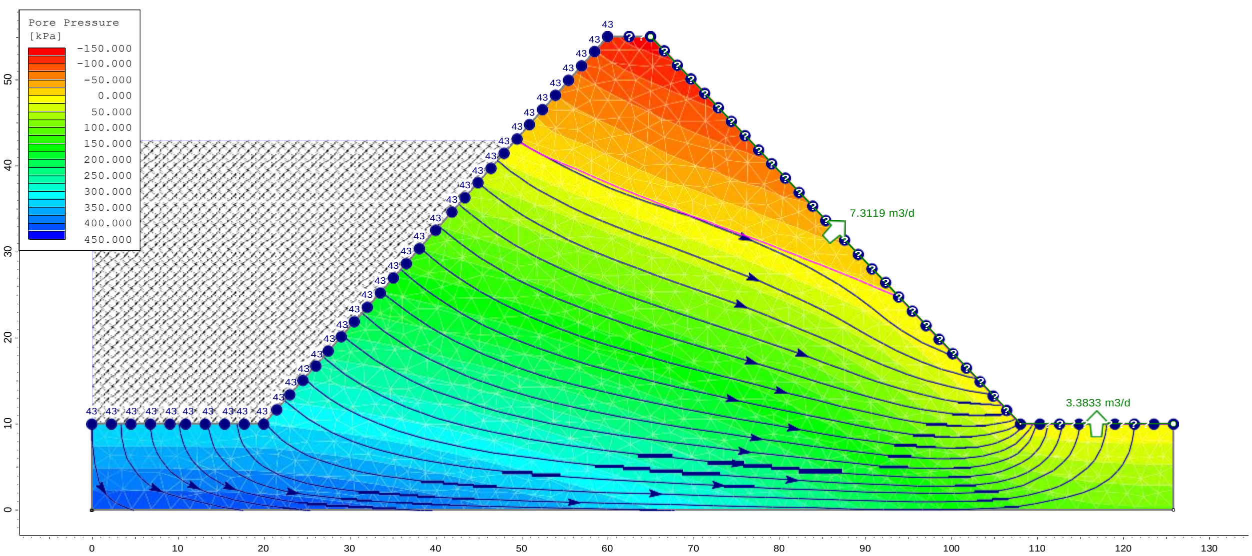

Figure 10- variation in pore pressure

4- Variation of horizontal discharge velocity

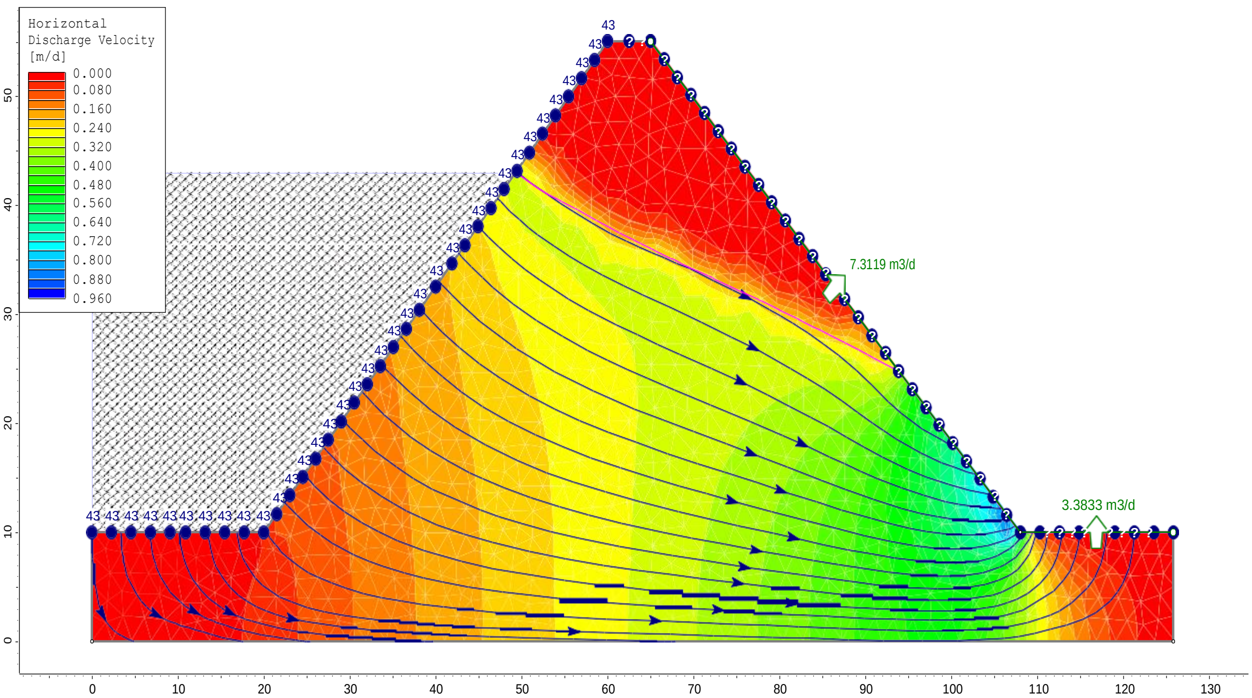

Figure-11 variation in horizontal discharge velocity

5. Variation in vertical discharge velocity

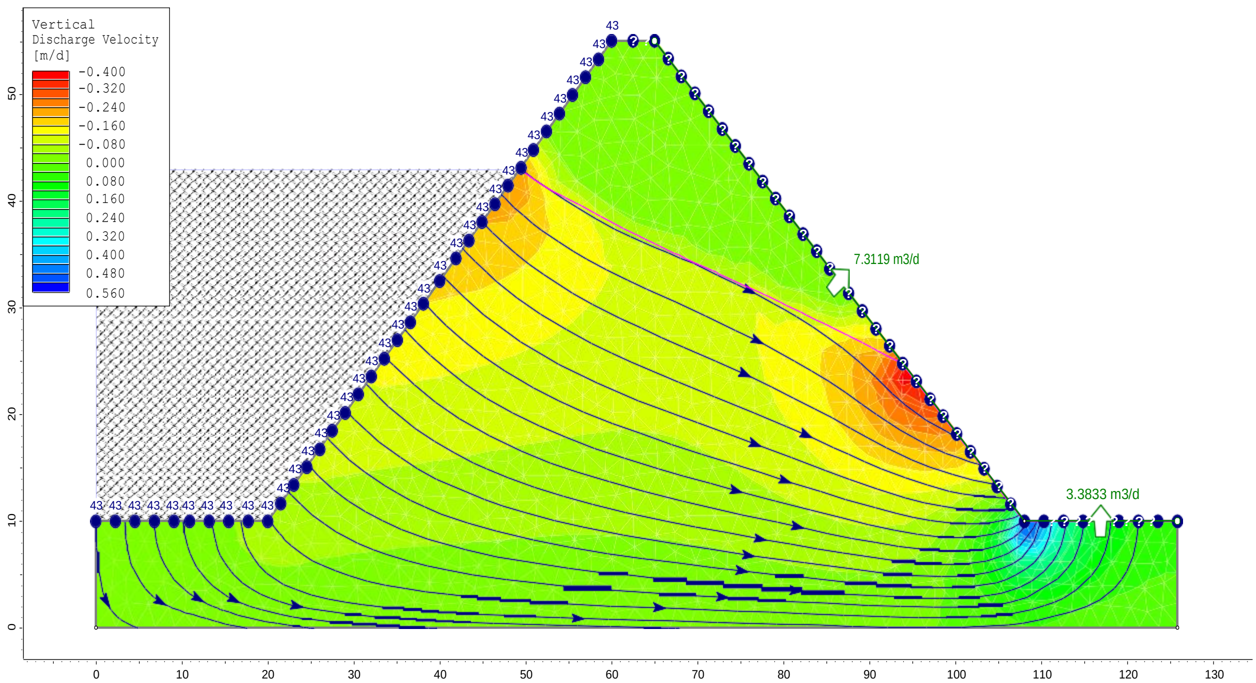

Figure 12-variation in vertical discharge velocity

6. Variation in horizontal hydraulic gradient

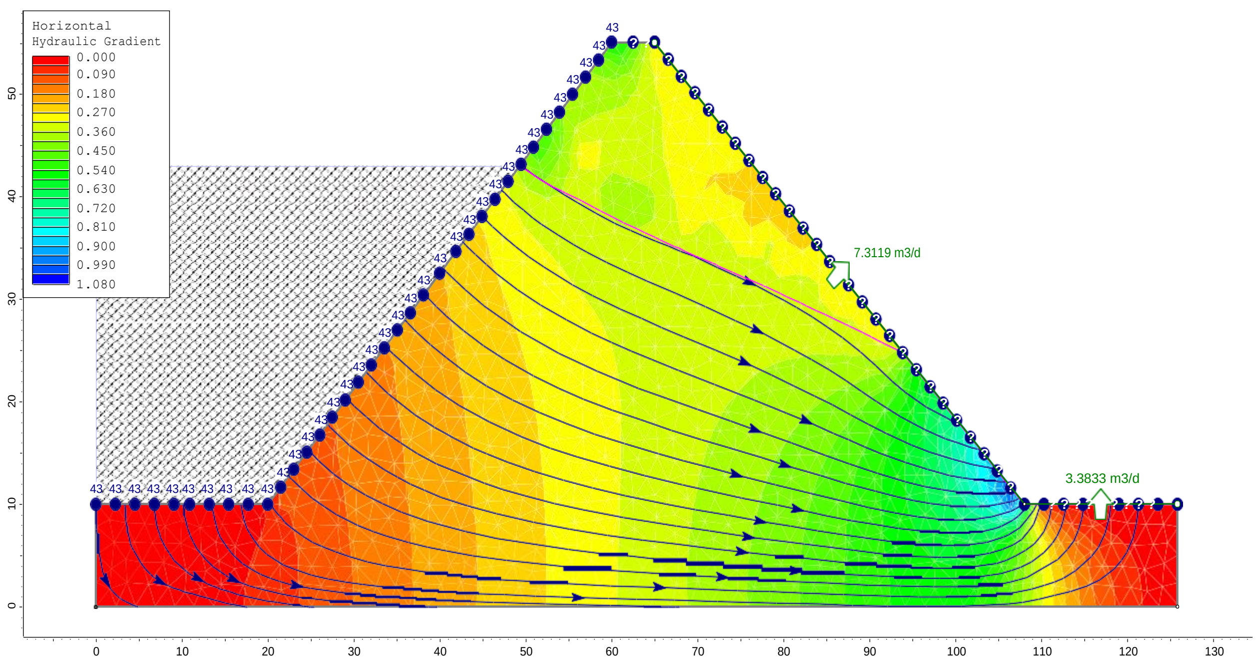

Figure 13-variation in horizontal hydraulic gradient

7. Variation in horizontal permeability

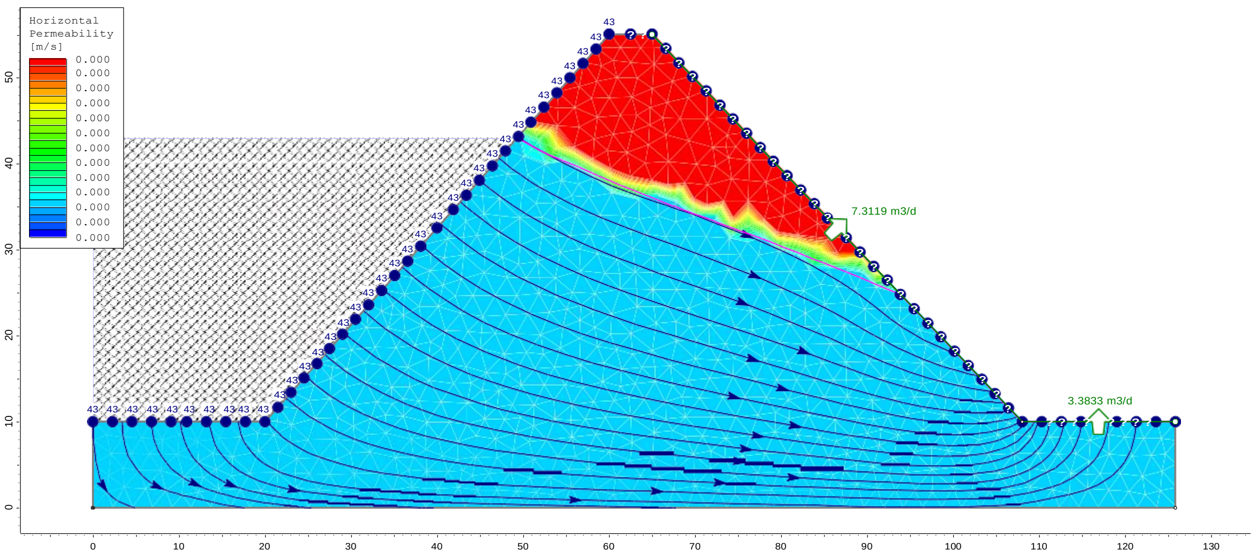

Figure 14-vaiation in horizontal permeability

8. Variation in vertical permeability

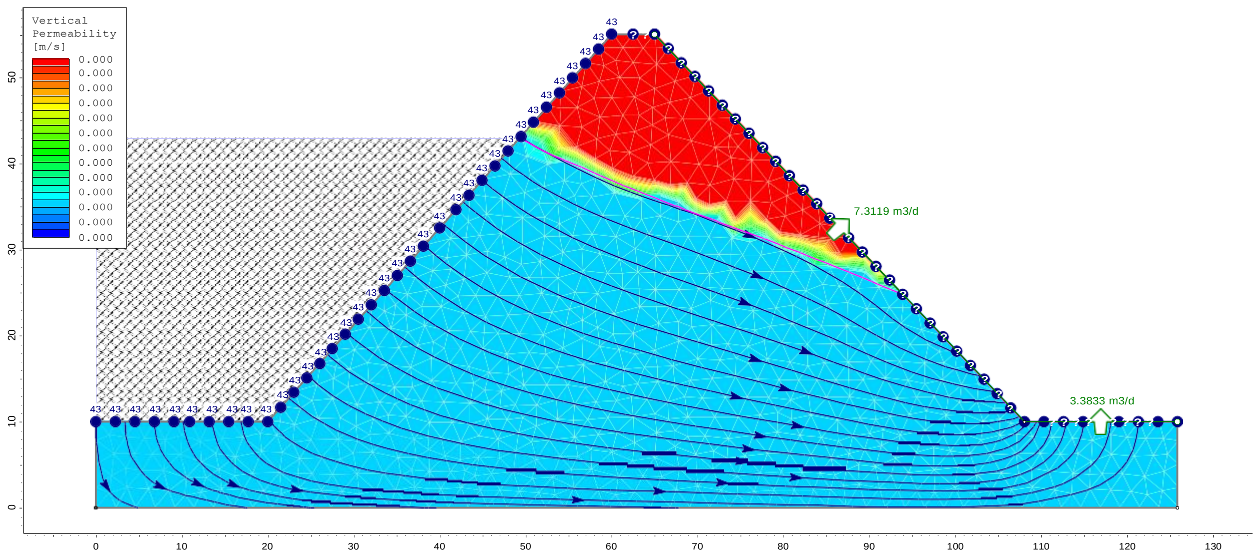

Figure 15-variation in vertical permeability

4.2 CASE 2- when a zoned earthen dam having core of clay with permeability, K= 1×10^{-10} m/sec and shell of medium grained sand of permeability K= 1×10^{-5} m/sec is analyzed.

<u>BASIC VIEW</u>

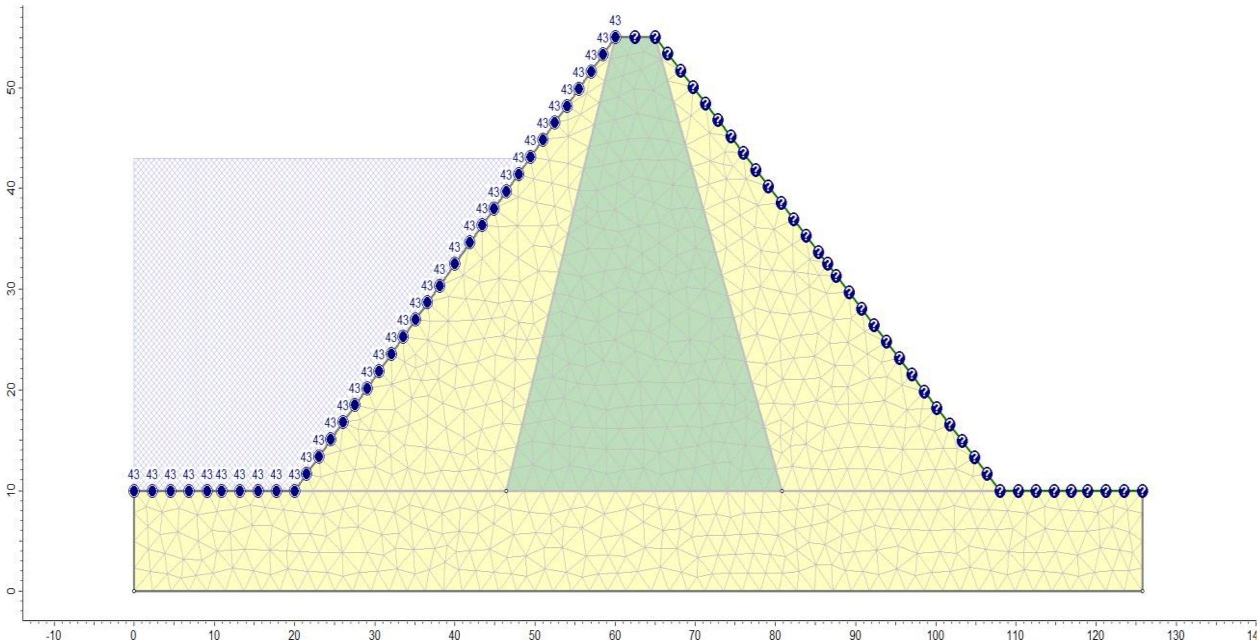

Figure 16-zoned earthen dam with a core

INTERPRETED VIEW

1. Variation of total head

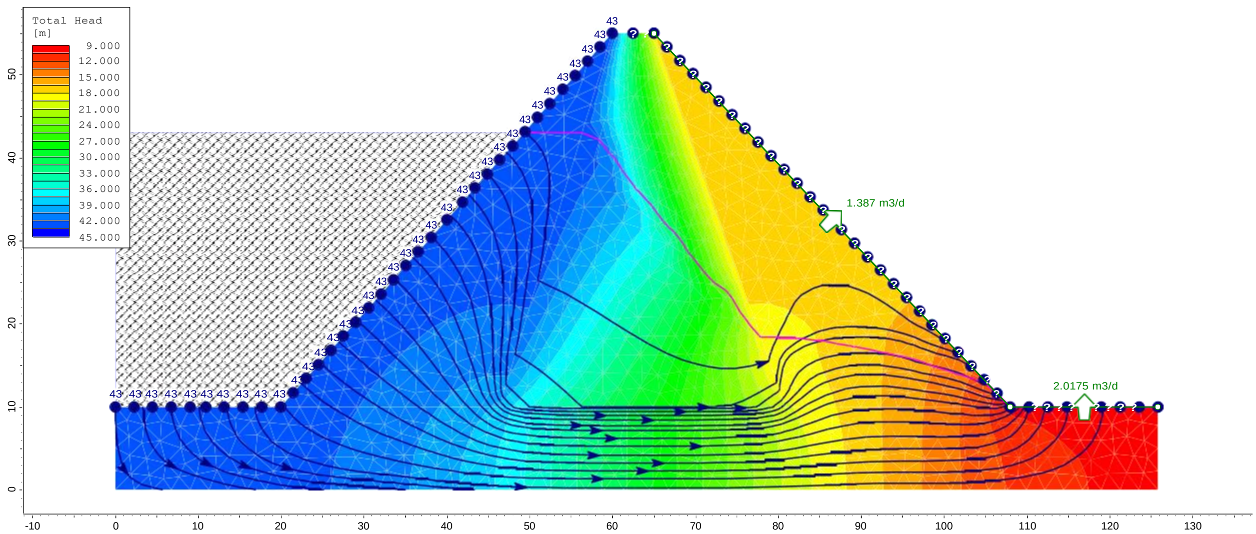

Figure-17 variation of total head in zoned earthen dam

2.Variation in pressure head

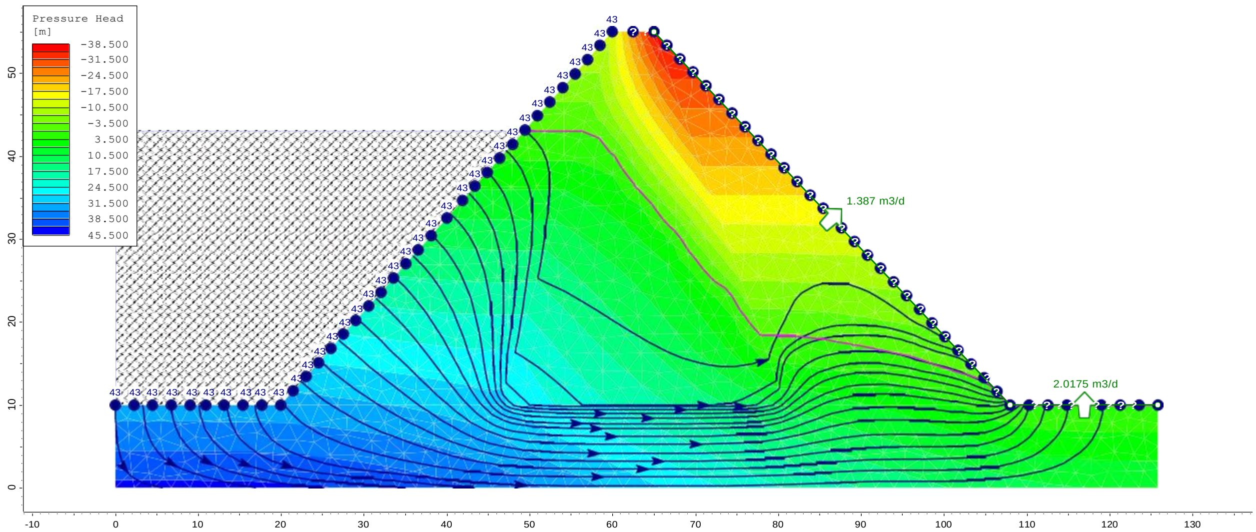

Figure 18-variation of pressure head in zoned earthen dam

3. Variation in pore pressure

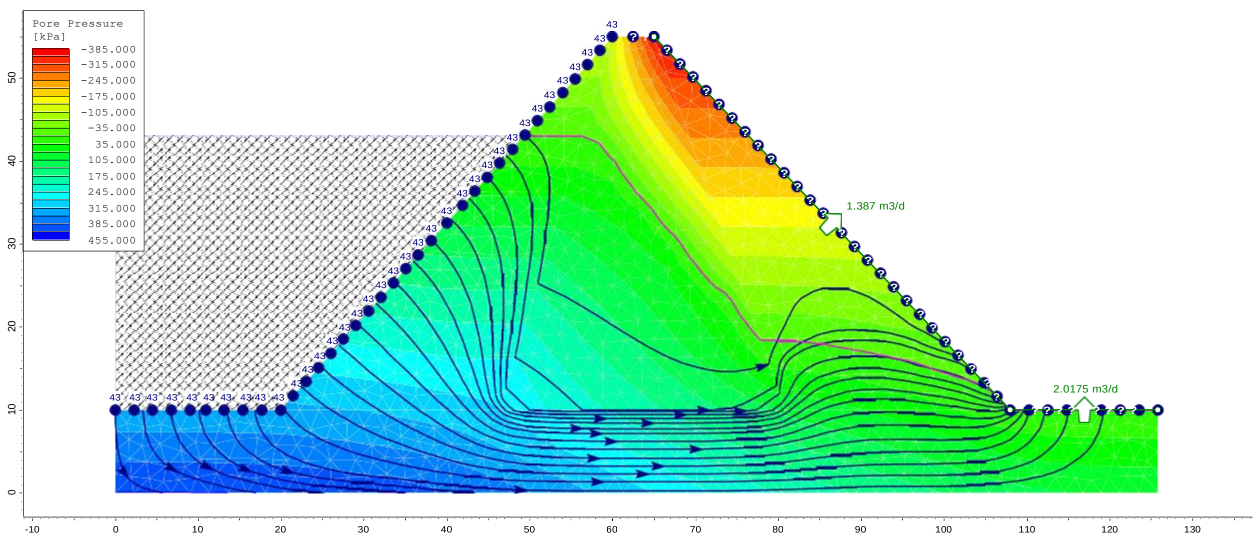

Figure-19 variation of pore pressure in zoned earthen dam

4. Variation in horizontal discharge velocity

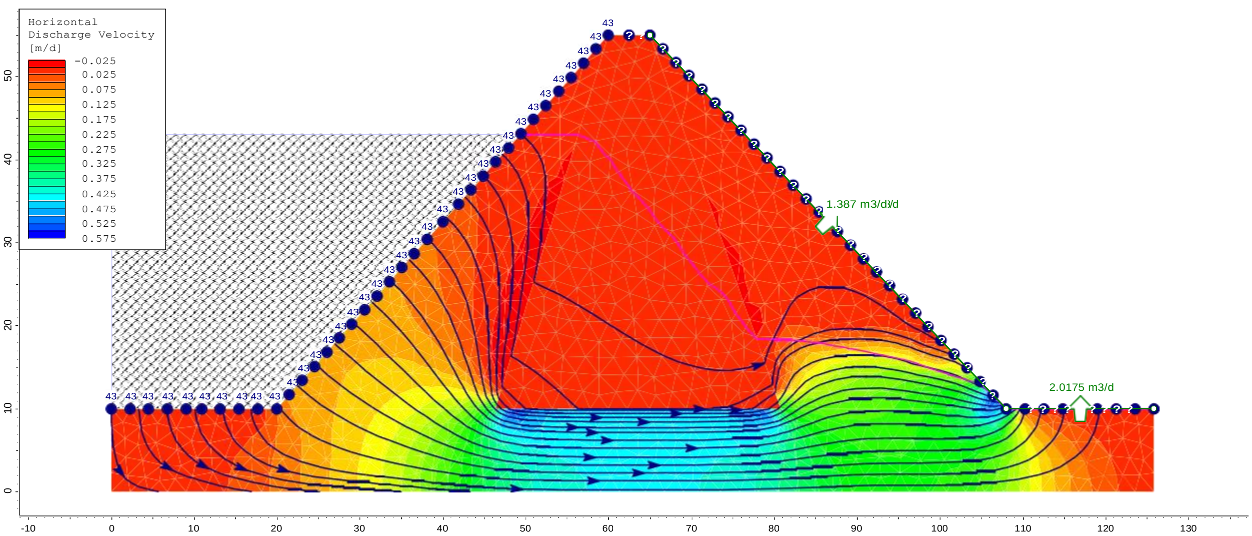

Figure 20-variation in horizontal discharge velocity of zoned earthen dam

5. variation of vertical discharge velocity

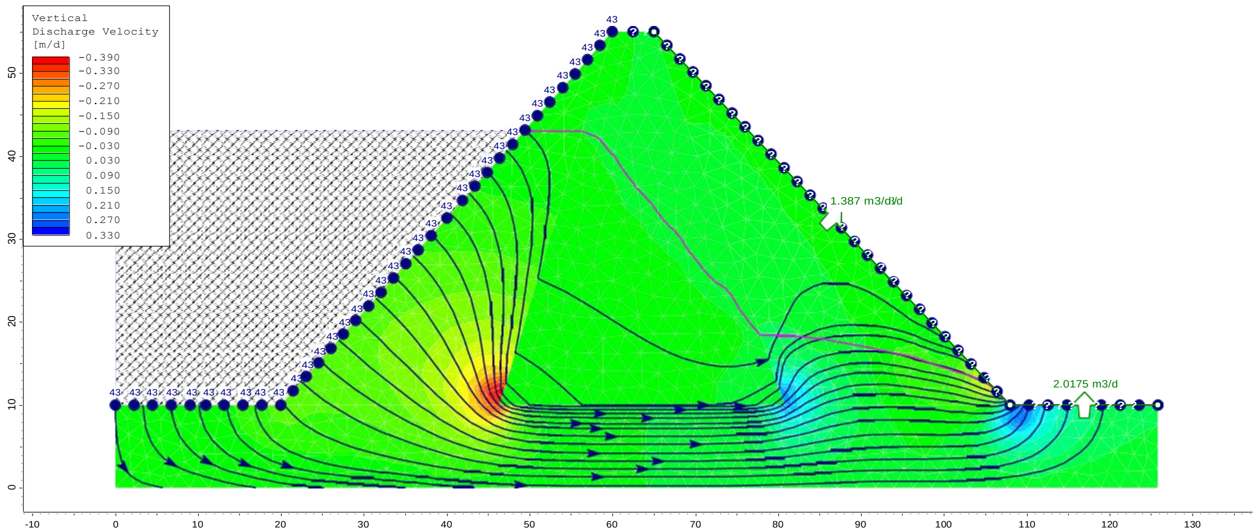

Figure 21-variation of vertical discharge velocity in zoned earthen dam.

6. Variation in horizontal hydraulic gradient

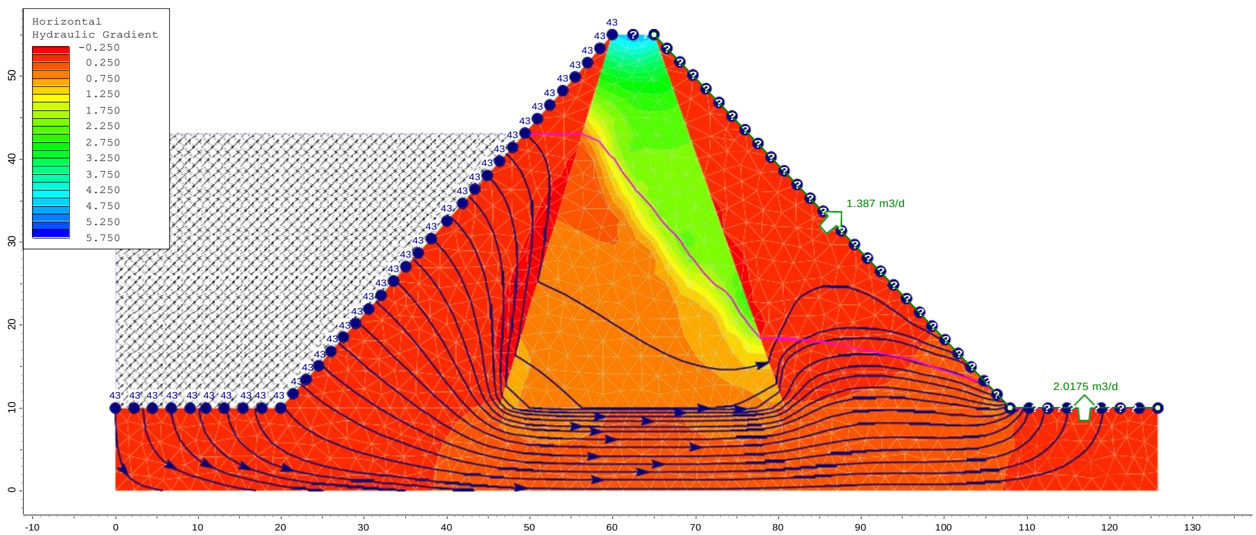

Figure 22- variation in horizontal hydraulic gradient in zoned earthen dam

7. Variation in horizontal permeability

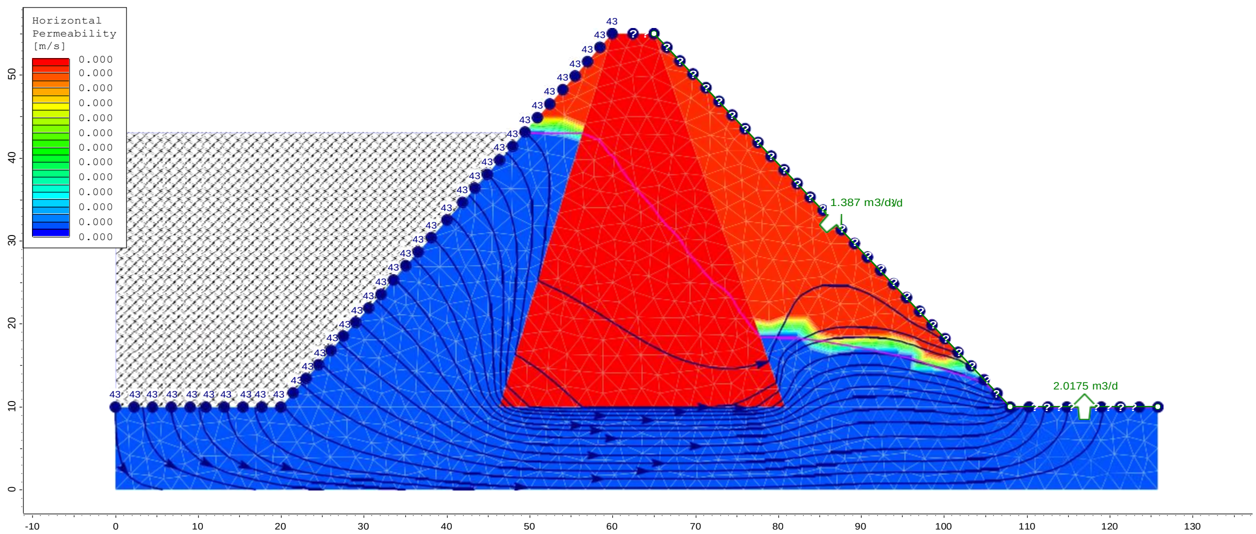

Figure 23-variation in horizontal permeability in zoned earthen dam

8. Variation in vertical permeability

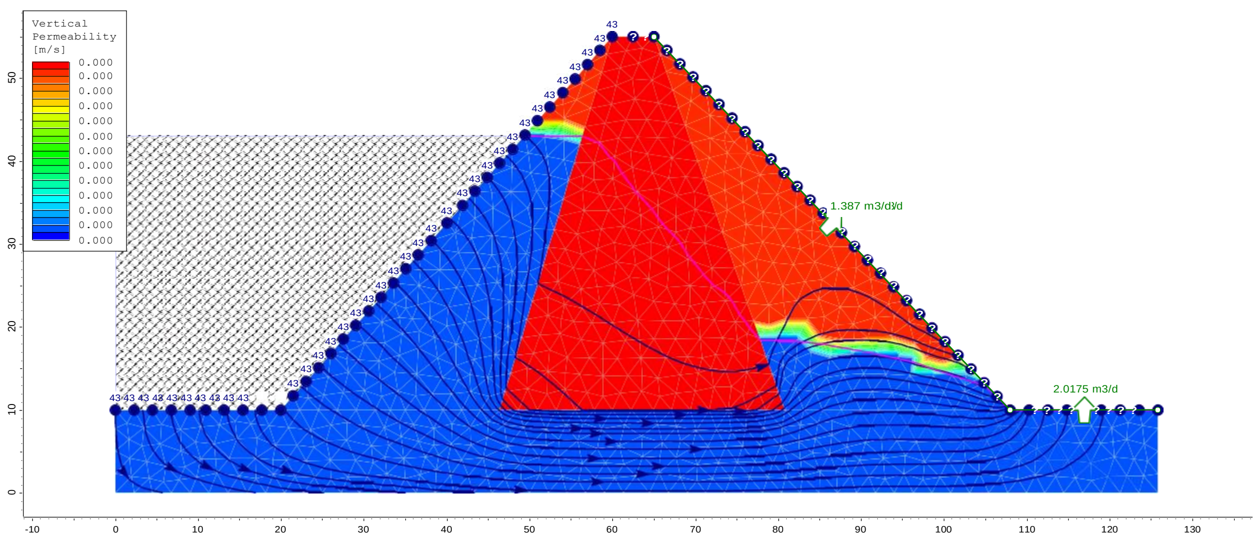

Figure 24-variation in vertical permeability in zoned earthen dam

RESULTS

Seepage Discharge through downstream sloping face in zoned earthen dam= 1.387 m^3/day

Seepage discharge through foundation in zoned earthen dam = 2.0175 m^3/day

Percentage reduction in seepage discharge through downstream sloping face after comparing cases 1 and 2= 81.03 %.

Percentage reduction in seepage discharge through foundation of dam after comparing cases 1 and 2 = 40.36%.

4.3-CASE 3 – In this case a cutoff wall having permeability, K= 1×10^{-10} m/sec is introduced throughout the depth of foundation.

BASIC COPY

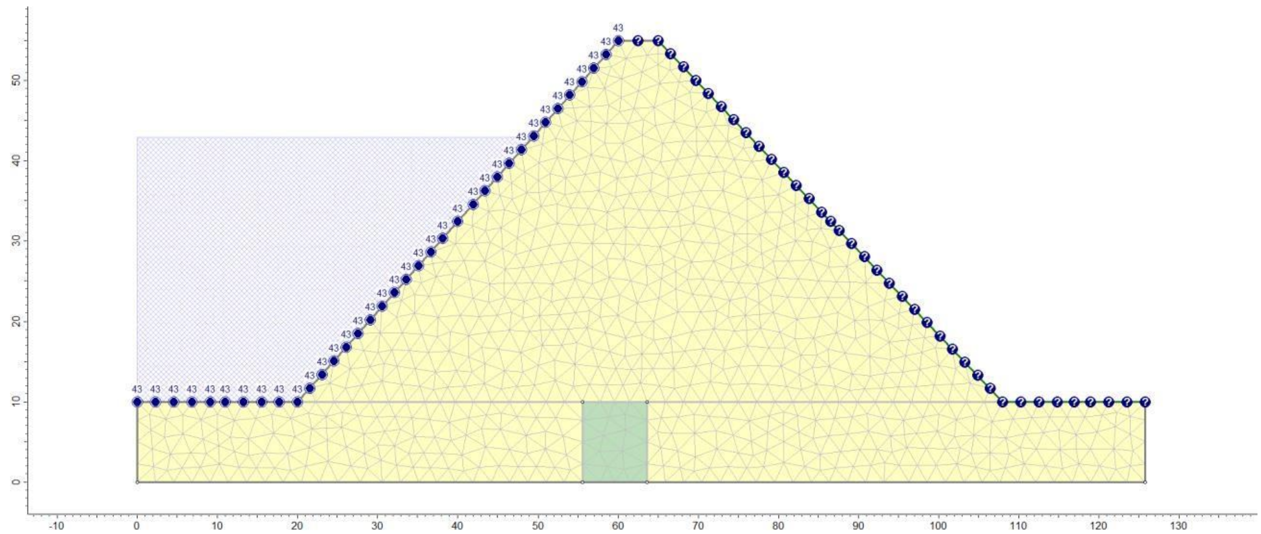

Figure 25-homogenous dam with a cutoff wall in foundation

1. Variation in total head

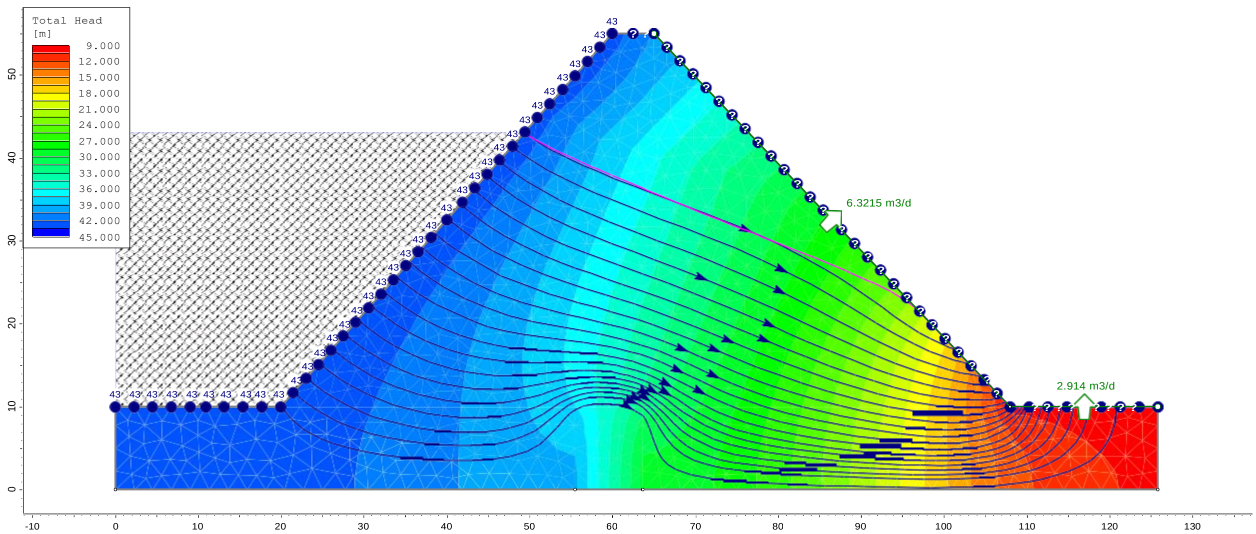

Figure 26- variation in total head in homogenous dam with a cutoff wall

2. Variation in pressure head

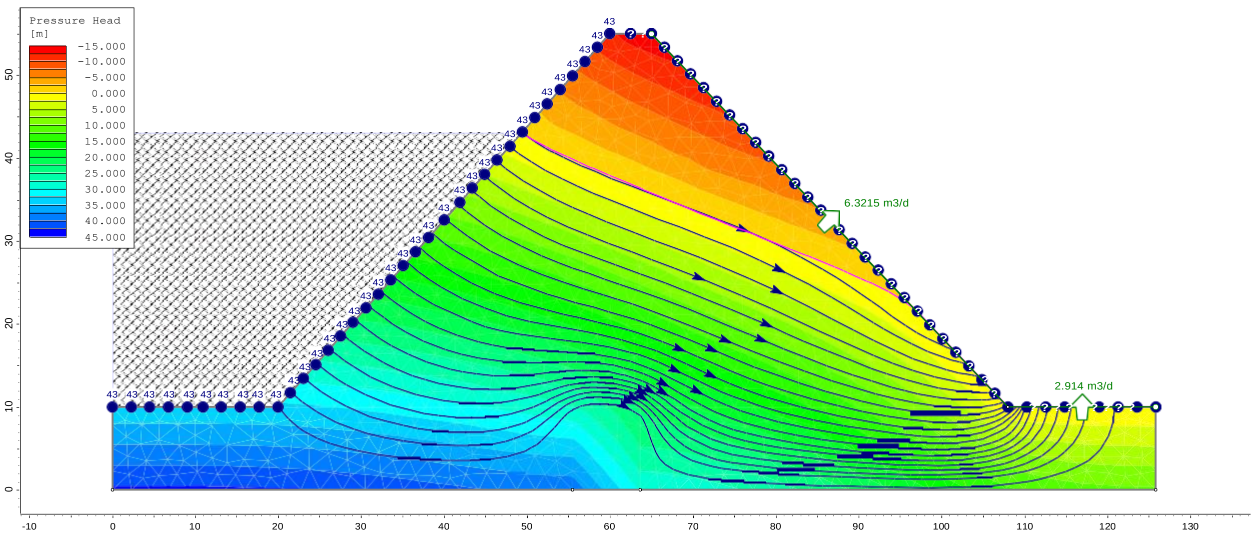

Figure 27- variation in pressure head in homogenous dam with a cutoff wall

3. Variation in pore pressure

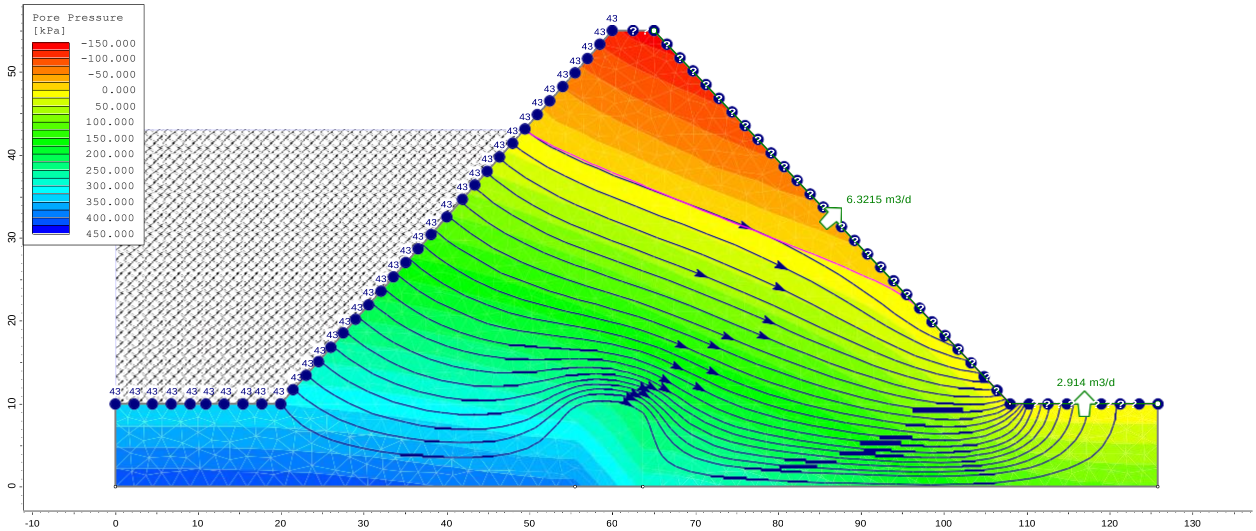

Figure 27- variation in pore pressure in homogenous dam with a cutoff wall

4. Variation in horizontal discharge velocity

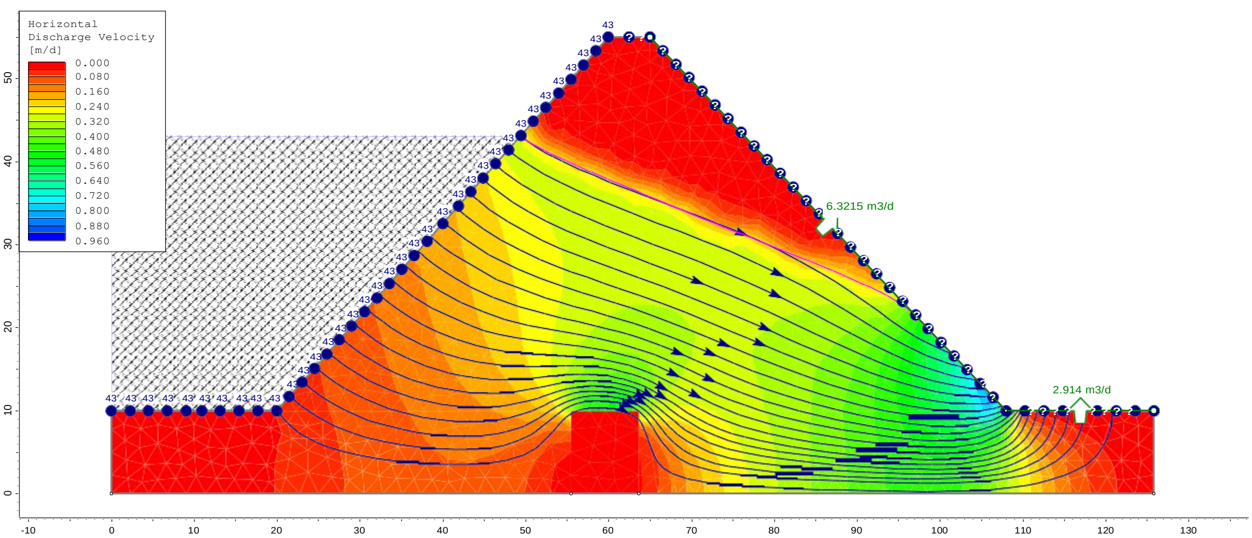

Figure 28- variation in horizontal discharge velocity in homogenous dam with cutoff wall

5. Variation in vertical discharge velocity

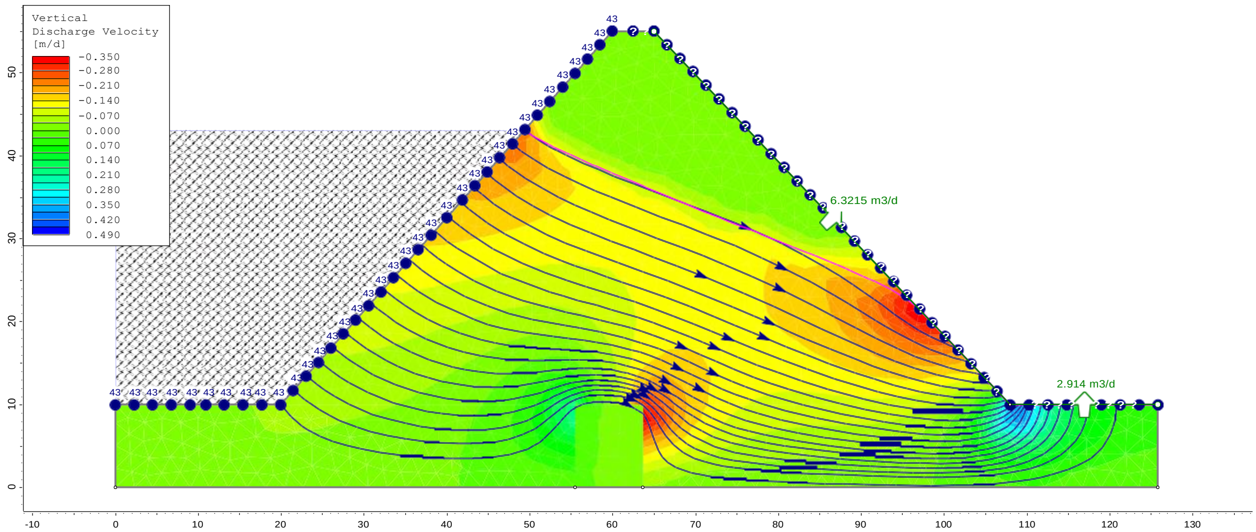

Figure 29- variation in vertical discharge velocity in homogenous dam with cutoff wall

6.Variation in horizontal hydraulic gradient

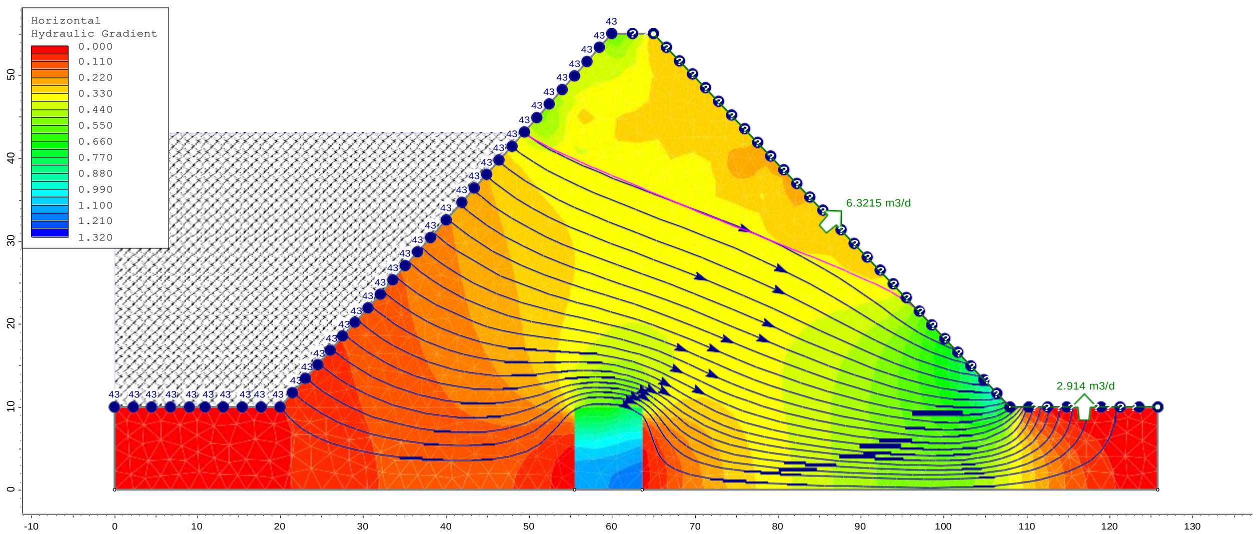

Figure 30- Variation in horizontal hydraulic gradient in homogenous dam with cutoff wall

7. Variation in horizontal permeability

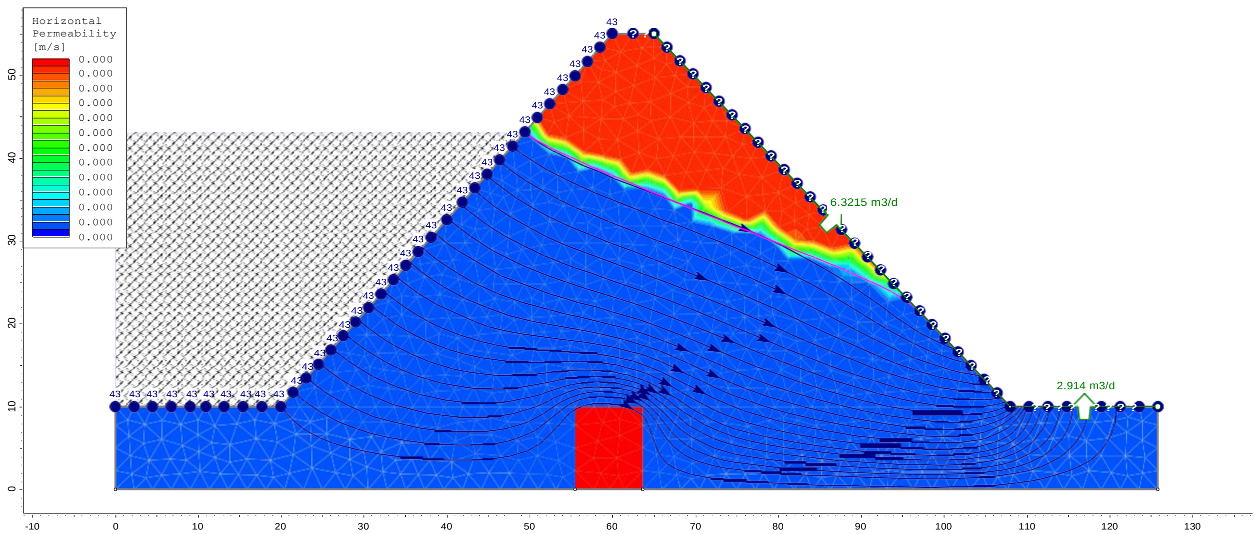

Figure 31-Variation of horizontal permeability in homogenous dam with cutoff wall

8. Variation in vertical permeability

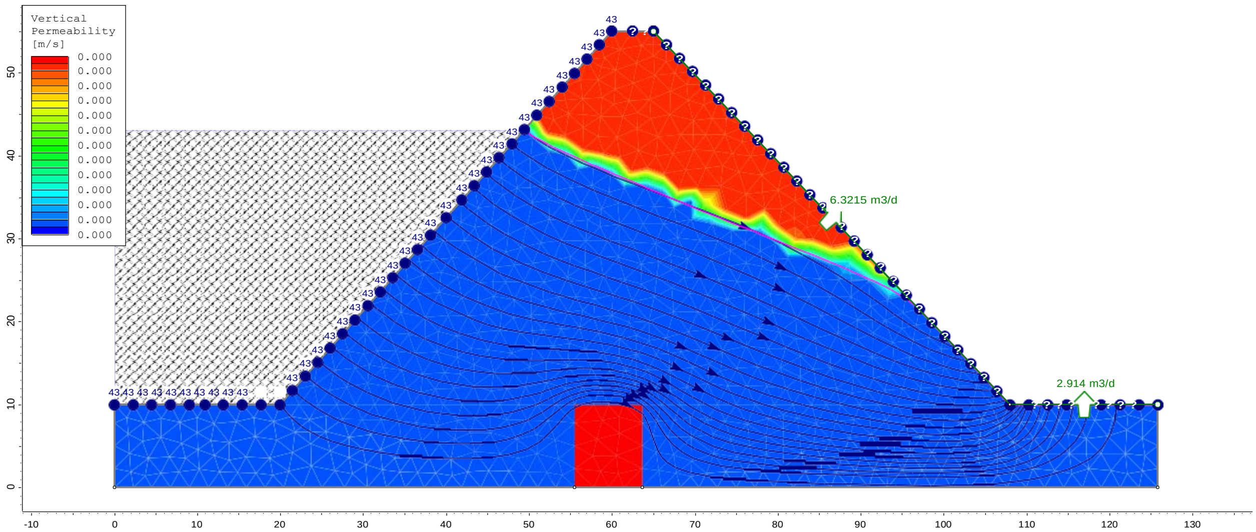

Figure 32- variation of vertical permeability in homogenous dam with cutoff wall

RESULTS

Seepage discharge through downstream sloping face = 6.3215 m^3/day

Seepage discharge through foundation = 2.914 m^3/day

Percentage seepage reduction through downstream sloping face when case 1 and case 3 are compared = 13.54%.

Percentage seepage reduction through foundation when case 1 and 3 are compared =13.87%.

CHAPTER -5

CONCLUSION AND FUTURE SCOPE

CONCLUSION

In this study, three different cases of Matatila Dam, Lalitpur, (Uttar Pradesh) are analyzed and results have been formulated with the help of Slide Software. Variation of various parameters such as total head, pressure head, pore pressure, horizontal discharge velocity, vertical discharge velocity, horizontal hydraulic gradient, horizontal permeability and vertical permeability are also shown with the help of figures in the result section for all the three cases. It was further concluded that;

- Seepage discharge through downstream sloping face and foundation of the homogenous dam was reduced by 81.03% and 40.36% respectively when homogenous earthen dam was replaced by zoned earthen dam having core made up of less permeable material (clay).
- Similarly when a cutoff wall was introduced at the foundation of homogenous earthen dam , the reduction in seepage discharge through downstream sloping face and foundation was reduced by just 13.54% and 13.87% respectively.
- So using zoned earthen dam with less permeable core material is a better option than introducing cutoff wall in the foundation of a homogenous earthen dam.

FUTURE SCOPE

The above work can be extended in future through experimental analysis in laboratory by making a model of the dam with a suitable scale ratio. Data obtained through experimental analysis can be compared with the present study and a comparative study can be done to calculate the relative error

CHAPTER 6

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