Seepage Analysis of Gangapur, the Earthen Dam Using Geo-Studio Software

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Abstract -The main purpose of this study is to find out the seepage loss through the earthen dam. Seepage is the main cause of failure of earthen dam and the seepage through earthen dam can be find out by different method or by using various software's. The seepage investigation through earthen dam is important to find out the seepage loss through earthen dam by providing various means like by providing horizontal toe drains, vertical toe drains, and seepage through earth dam with an internal core. Earth-fill dams are simple structures which are able to prevent the sliding and overturning of dams because of their self-weight. Due to lack of suitable clay materials, sometimes the dams are designed as zoned core that is composed of three vertical zones including central impermeable core and two permeable shells on either sides of the core. A failure of earth dam is attributed to the following: hydraulic failure, seepage failure, piping through dam body and structural failure due to earthquake. On completion of this swot up it is concluded that the seepage loss through this dam is important and it shows that the dam is safe against seepage loss.

In this investigation the seepage analysis is done on Gangapur dam near Nasik city in Maharashtra. The Gangapur dam in Nashik, the longest earthen dam in Asia was constructed in year 1954. This dam has built on the river Godavari in the outskirts of Nashik city. This was the first dam to be built in the district. This dam is located at Gangawadi village which just is 10 kms away from the Nashik. Gangapur dam has a catchment area of 357.4 Sq.km and maximum height of 36.57m. There are two canals channelizing water from the dam to the surrounding areas. The right bank canal is just 30 kms length, while the left bank canal is 64 km in length. This dam can discharge 81013 cusecs (2294 cumecs) of water through its 9 radial gates.

The results obtained from Geo-studio software are more accurate than manually calculated and it is concluded that the dam is safe against any loss caused due to seepage through the dam and the results are 10.3% greater than the manually calculated.

Index Terms: **seepage, seep/ w, earthen, earthfill, Geo-studio**

I. INTRODUCTION

1.1 General

Dams are mainly constructed of earth and rock-fill materials, the earth-fill dams are simple structures which are able to prevent the sliding and overturning because of their self-weight. Due to lack of suitable clay materials, sometimes the dams are designed as zoned core that is composed of three vertical zones including central impermeable core and two permeable shells on either sides of the core. A failure of earth dam is attributed to the following: hydraulic failure, seepage failure, piping through dam body and structural failure due to earthquake. The design and construction of an earth-fill dam is one of the key challenges in the field of geotechnical engineering, because of the unavoidable variation in foundation condition and the properties of the available construction materials. A homogeneous earth-fill dam should be designed with relatively flat slopes to reduce the risk of failure. The practical seepage problems are not easily convertible into an equivalent numerical counterpart because of the heterogeneity of the natural soils and the varying boundary conditions

The present study was carried out to find the seepage analysis of earthen dam using Geo-studio software. From the literature and the calculated seepage, it is clear that seepage models for seepage analysis of earthen dam are more efficient than the other manually calculated methods. The seepage analysis is done using daily water level of Gangapur dam for 15 year. Comparing observed data and the estimated data through Geo-studio models, it has been proved that the Geo-studio models show good results and are better than the manually calculated.

1.2 Objectives of the present Study

The conventional mathematical techniques in the form of regression equations do not provide a perfect representation of seepage. The main objective of the present study is to develop models for prediction of seepage for one year ahead using GeoStudio software the specific

Main objectives of the present study are:

Estimation the phreatic surface within an embankment.

Calculate pore pressures within an embankment or foundation.

To estimate exit gradients and/or uplift pressures at the toe of an embankment.

To estimate the amount of seepage flow that may pass through an embankment or foundation.

To evaluate the relative effectiveness of various seepage reduction measures.

To estimate the amount of seepage flows intercepted by drainage features and to size and optimize the configuration of these types of drainage features.

To evaluate the effectiveness of, or to aid in the design of, dewatering systems.

The present work explicates seepage analysis of Gangapur, the earthen dam by using Geo-studio, a relatively latest software mainly in seepage modelling.

1.3. Problem considered for analysis and computation:-

The following problems are to be considered for analysis and computation:

Development of flow net by tracing streamlines and equipotential lines for different conditions.

Observation of velocity vectors and thereby seepage behaviour for different conditions.

Profile of the phreatic line for different conditions.

Estimation of seepage quantity through the dam profile and its foundation for different conditions.

Computation of Exit gradient, maximum velocity and Residual head along the dam foundation under different conditions.

The slide is nothing but breakdown of volume of soil in downward direction. It is approximately caused by a slowly disintegration of the soil structures, by an increasing of pore- water pressure in a few more permeable layers, or by a shock that liquidizes of soil. The main factor for increasing of pore-water pressure the soil is failed in shear strength. The falling of shear strength may occur due to shock loads, rise in water content, varies in pore water pressure, weathering or any other cause. Most of numerous slopes failure occurs during rainy season, as an including of moisture content causes both increased stresses and the loss of strength with the development of modern method of technique of stability investigation, a safe and cost of design of a slope have a thorough knowledge various methods for checking the failure of slopes and their restrictions. The SEEP/W and SLOPE/W computer software can be used to estimate the flow of water through the soil and failure slope analysis of earthen dam. This software solves the underground water problems for stable, unstable, wet and dry conditions. This software not only the superiority to the graphic method and manual calculations, but also regarding the time we can gain good results. This software has many applications which helps designers in best designing of dams and analysing the weak or strength points of dams and also designing of the construction which dealing with the seepage problems.

1.3.1. Intents of Study

1. Study the earthen dam details.

2. Study the causes of failures of earthen dam.

3. Calculation of seepage and slope stability analysis in earthen dam by the analytical approach.

5. Determining the seepage analysis by using geo-studio software in earthen dam.

6. Determine the slope stability analysis by using geo-studio software in earthen dam.

II. LITERATURE REVIEW

There are Geo-studio software techniques available in the literature to assess, simulate and predict seepage. However, the selection normally depends on the availability of required input data, objectives of the study, some predefined assumptions and the quality of available models. Therefore, the choice of a model is one of the important factors that will influence the predicting accuracy.

The following papers are used to complete the literature review for the project.

A. Kamanbedast et al. (2012) compared two softwares to calculate seepage through dam. They also attempted soil stability of Dam using Ansys. Firstly, Dam was studied by using analysis method, then seepage are predicated the seepage Rate in Ansys, 18% percent is lower than Geo studio results. Besides, Slope Stability is studied and different behaviour of dam is simulated. The obtained results of Ansys and Geo studio Software were compared. Fatemeh Karampoor et al. (2015) studied survey effect of the clay core in seepage from non-homogeneous earth dams using SEEP/W, the software suite Geo studio finally, by comparing the values of dimensional analysis with Excel software. They investigated the effect of each of the clay core characteristics the seepage of the homogenous soil dams. Data analysis software model seep / w, dimensional analysis and software SPSS found that: The flow rate increases with increasing upstream head and decreases with increasing flow rate through the downstream head. Dr. Raad Hoobi Irzooki(2015) focused on the seepage discharge increased with increasing upstream slope, downstream slope, upstream reservoir water depth and length of horizontal toe drain. Also, the results show that the seepage discharges decreased with increasing the top width of the dam and the height of the free board. Using SEEP/W results with helping a dimensional analysis theory, a new easy and reliable empirical equation for computing seepage discharge through homogenous earth dams with horizontal toe drain was developed. Sayyid Ehsan Hosainy et al.(2015) concluded that the seepage rate reduced approximately 9% with increasing the length of cut-off wall. Seepage rate reduced approximately 7.3% with covering concrete slab on the dam’s wall. Seepage rate reduced approximately 3% when the clay blanket on the bottom of the dam used. The results illustrated the actual seepage rate is different about 8% from the software results. Amin Fakhari et al.(2013) studied almost 600 geometric models of embankment dam with clay core to solve it numerically. They compared the obtained results using numerical simulations and the equations proposed by other researchers. The above-mentioned comparison shows that the proposed equations are capable of predicting seepage of embankment dam body with high precision. . Comparing the results obtained from the equations suggested with the Seep/W shows that except in limited cases, in other cases, the errors of the equations are in acceptable range. Tatewar S. P. et al.(2012) presented stability analysis, carried out on 21 m high “Bhimdi earth dam” situated near Tq. Warud Dist. Amravati (Maharashtra State) by changing different parameters such as changing berm width, changing position of filter drains and to gain desire stability how much strengthening required that was carried out by using software Geo-studio. The Existing design results were compared with the simulated results obtained from software.and the results are more acceptable than the manually calculated methods. Pavan N et.al(2016) utilized the geo-slope software seepage and stability investigation in ramanahalli earth fill dam is examined SEEP/W software for seepage analysis. Four lattice size properties for example coarse, medium, fine and unstructed cross section was assess to evaluate the type and size of mesh on the total flow rate and total head through the dam cross section. Result showed that average flow rate of seepage under the mesh size of 1.5m for ramanahalli dam equal 2.9e-009m3 /sec for middle of dam. Asmaa Abdul Jabbar Jamel(2016) studied the quantity of seepage through homogenous earth dam without filter resting on impervious base using computer program SEEP/W (which was a sub-program of Geo-Studio). The comparison suggested that the equation with artificial neural network (ANN) less than 3% error with SEEP/W results less than 2% error, Dupuit’s solution has more than 20% error and Casagrande’s solution has more than 15% error.

From the above study it is concluded that the Geo-studio software is best option for finding out the seepage loss for the earthen dam and all methods are not much more accurately gives the results than Geo-studio software.

Study Area and Methodology

Study Area

Gangapur dam near Nashik, Maharashtra, and the longest earthen dam in Asia was constructed in year 1954. This dam has built on the river Godavari in the outskirts of Nashik city. This was the first dam to be built in the district. This dam is located at Gangawadi village which just is 10 kms away from the Nashik. Gangapur dam has a catchment area of 357.4 Sq.km and maximum height of 36.57m. There are two canals channelizing water from the dam to the surrounding areas. The right bank canal is just 30 kms length, while the left bank canal is 64 km in length. This dam can discharge 81013 cusecs** (2294 cumecs) of water through its 9 radial gates. (**1 Cusec = 7.48 Liters) Coordinates: 73°40'57"E 20°2'6"N

Table 3.1.1 Location and catchment area of Gangapur dam

Dam Name	Gangapur Dam
State Name	Maharashtra
Type of dam	Earthen
Owner	Government of Maharashtra
Built By	Maharashtra Tourism Development Corporation
Nearest City	Nashik
Impounds	Godavari river
District Name	Nashik
Catchment Area	357.4 km2
Lat / Long	20.048141, 73.679799
Total Storage Capacity	215,880.00 km3
Purpose	Irrigation
Construction began	In 1954
Opening date	In 1965
Height	36.59 meters
Length	3,902 meters
Dam Volume Content	4220 Tcm
Spillway Gates	9
Spillway Type	Ogee
Type of Spillway Gates	Radial
Project	Gangapur Major Irrigation Project

Apart from the dam related functions, the Gangapur dam is a great spot for several outdoor activities. This is an amazing spot just near to Sula vineyards, so you can always mix the trip to Sula vineyards with Gangapur dam. A short walk to the barren land might lead you to the lake formed by Gangapur dam. You can watch the moonrise from the top of the dam. You can spend some happy time at the garden nearby the dam which serves as a good picnic place, but you have to get the permission from the chief executive engineer of the dam. If you are a environment lover, you might find some interest on the algal forms of taxonomic groups in the Gangapur dam's fresh water ecosystem. This dam is built up of clay, stones, and mud and sand materials. It is also count as one of the biggest dams built on the Godavari River. Gangapur dam supplies range of benefits including river navigation, water supply, and waste management and maintains ecological balance. The dam also has a religious perspective as it accumulates the water from sacred Godavari River. On weekends, you can see good crowd, especially the young.

3.1.1. Specifications of dam:-

The height of the dam above lowest foundation is 36.59 m (120.0 ft) while the length is 3,902 m (12,802 ft). The volume content is 4,612 km3 (1,106 cu mi) and gross storage capacity is 215,880.00 km3 (51,792.37 cu mi). Due to silt deposition in the reservoir area, the storage capacity of the dam has gradually reduced. The right side canal running towards Nashik is also closed due to the high civilization in the area. For these two reasons, an upstream dam, Kashypi Dam, is constructed which opened in 1998.

This dam is near village Gangawadi and is 10 Km. from Nashik city. This is a earthen dam constructed between 1954 and 1963. The total catchment area of the dam is 357.4 Sq.km. The total dam length is 3810 m. and maximum height of the dam is 36.57m. The total Gross storage of the dam is 215.88 MCM (7624 mcft) and total Live storage is 203.76 MCM (7200 mcft). The lenght of the waste weir is 102 m. There are total 9 radial gates of size (9.15x6.10 m.) having the discharge capacity of 2294 cumecs (81013 cusecs). The dam has two canals, the left bank canal is 64 Km. long and right bank canal is 30 Km. long. The total irrigable area of this dam is 15960 Ha. Due to deposition of silt, storage capacity of Gangapur Dam reduced to 5630 mcft also due to increase in residential zone (civilization) in command area of Nashik Right Bank canal is closed since 2006 and the land has been given to Nashik Municipal Corporation for laying pipeline for drinking water from Gangapur Dam. In order to overcome the storage loss, Kashyapi Dam has been constructed on the upstream. The water from Gangapur Dam is used for irrigation through Nashik Left Bank canal, Godawari canal in Ahemadnagar district and drinking purpose of Nashik Municipal Corporation M.I.D.C. satpur /Ambad , Thermal Power station Eklhare & recently reused water received after Nashik Municipal Corporation treatment is given to India Bulls Realtech Co.Ltd. (IRC) for their Thermal power plant at sinnar.

Figure 3.1.1.Index map of Gangapur dam

Collection of data:

All the data was collected from the, Water Resource Department Nasik, Government of Maharashtra

3.3. Model Formulation Using Geo-studio software

In this study, SLOPE/W, in one form, or another has been on the market since 1977. The initial code was developed by Professor D.G. Fredlund at the University of Saskatchewan. The first commercial version was installed on mainframe computers and users could access the software through software bureaus. The modelling technique approach used in the present study is based on seepage analysis of Gangapur dam using Geo-studio software. Geo-studio can be incorporated effectively to enhance understanding and enabling the researcher actively to put theory into practice. This software is known are user friendly and flexible with high capability for analysis of seepage loss. Results of this study will permit the identification of the best models for the seepage analysis. For Gangapur dam the models are developed by using 70% of available data for training, 15% data for testing and 15% data for validation purpose.

3.3.1. Software: SEEP/W

GEOSTUDIO software is one of geotechnical program that is based on the finite element and can do analysis such as, stress-strain, seepage, slope stability, dynamic analysis. SEEP/W (Seepage for Windows) is a finite element software product that is coming under GEOSTUDIO, used to model the movement and pore-water pressure distribution within porous materials like soil and rock. It is formulated on the basis that flow of water through saturated soil follows Darcy's Law. The SEEP/W model is constructed to solve 2-dimensional flow situations with multiple soil layers. Flow directions of groundwater can be analyzed. Under steady state conditions, the difference between input flux and output flux is zero at all times. For finite element calculations, the SEEP/W model is divided by nodes. The elevation of water level at each node is calculated. In the SEEP/W models, the following assumptions are made: (i) the aquifer is heterogeneous and isotropic, and (ii) the aquifer is partly confined and partly unconfined. Good quality output graphics allows a visual display of equipotential lines and flow paths, and contours can be plotted for different properties like pore pressures, seepage velocities, and gradients. Computations include flow quantities and uplift pressures at user-selected locations in the model.

3.3.2. Model formulation of Geo-studio software for contour map of dam:-

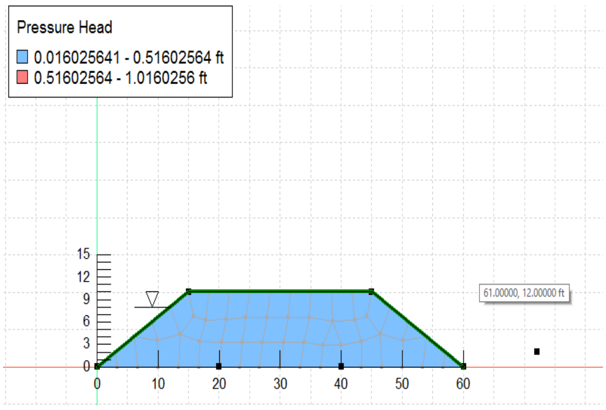

Fig 3.1.2-Contour map for pressure head of dam section

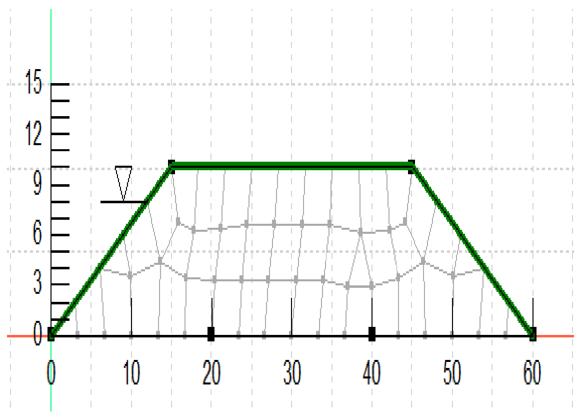

Fig 3.1.3- static water level of dam with zero water pressure

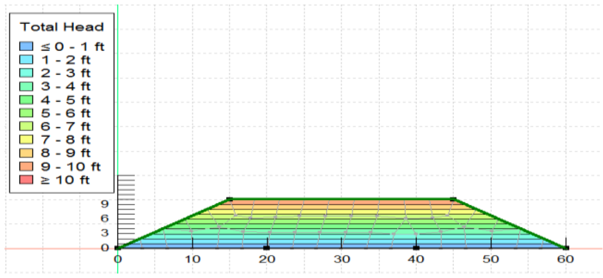

Fig3.1.4-contour map at total head for dam section

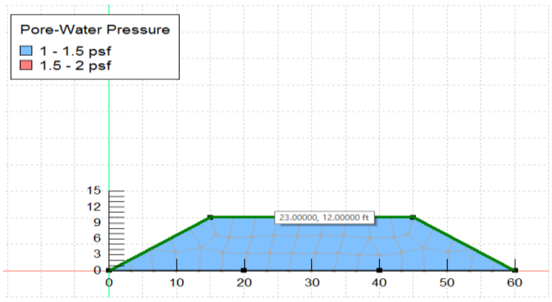

Fig 3.1.5-contour map for pore-water pressure for dam section

III. RESULT AND DISCUSSION

4.1 General

The above developed model for seepage analysis of Gangapur dam using Seep/w software are compared with manually calculated data it is found to be more efficient than the manually calculated data.

4.2 Results of Seep/w model

Table 4.2.1 Seepage loss using Seep/w model between the observed and predicted discharge values for models developed for seepage loss.

Seepage for Gangapur dam:-

Table 4.2.1 shows seepage loos calculated manually using the daily water level of Gangapur dam.

Sr . no	Year	Seepage loss/year(cumecs)
1	June -2001-Dec-2001	0.841
2	Jan-2002-Dec-2002	0.076
3	Jan-2003-Dec-2003	0.034
4	Jan-2004-Dec-2004	0.014
5	Jan-2005-Dec-2005	0.087
6	Jan-2006-Dec-2006	0.005
7	Jan-2007-Dec-2007	0.044
8	Jan-2008-Dec-2008	0.021
9	Jan-2009-Dec-2009	0.025
10	Jan-2010-Dec-2010	0.093
11	Jan-2011-Dec-2011	0.163
12	Jan-2012-Dec-2012	0.040

13	Jan-2013-Dec-2013	0.040
14	Jan-2014-Dec-2014	0.126
15	Jan-2015-Dec-2015	0.044
16	Jan-2016-Dec-2016	0.065

4.2.1. Results of Seep/w model for unsaturated and saturated water content function 4.2.1.1. Hydraulic conductivity of dam for seepage analysis:-

From this table it is shows that the hydraulic conductivity of dam increase or decrease as the pore water pressure increases and the volume of water content increases the graph shows that the value of hydraulic conductivity depends upon the pore water pressure.

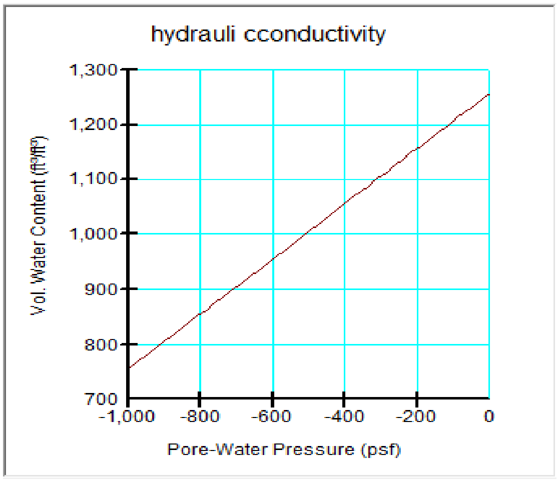

Fig.4.2.1-Hydraulic conductivity for upstream section of dam

Table 4.2.2–Hydraulic conductivity at downstream section of dam

For hydraulic conductivity	
Matric suction(Psf)	VWC(ft3/ft3)
0.11288	0.050387
0.20691	0.050387
0.37927	0.050387
0.695192	0.050387
1.274275	0.050387
2.33572	0.050387
4.28133	0.050387
7.28133	0.050387
14.3845	0.050387
26.36651	0.050387
48.329302	0.050387
88.58668	0.050387
162.37767	0.050387
297.63514	0.050387
545.55948	0.050387
1000	0.050387

4.2.1.2. Hydraulic conductivity for slope functions and pore water pressure at middle section of dam:-

From this table it is shows that the values obtained are more than the seepage at the upstream end of the dam.

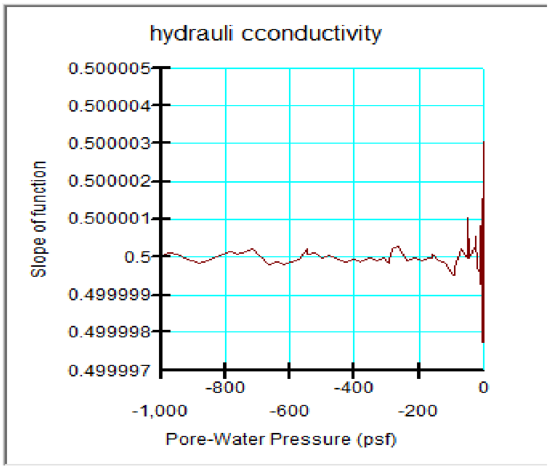

Fig 4.2.2- hydraulic conductivity for slope function and pore water pressure at middle section of dam

Table 4.2.3-Hydraulic conductivity for downstream section of dam

Hydraulic conductivity for dam at middle section	
Matric suction(Psf)	VWC(ft3/ft3)
0.01833	0.47358577
0.0335981	0.447151
0.0615848	0.420728
0.112883	0.394305
0.2069138	0.36788
0.379269	0.3414616
0.6951928	0.31504274
1.274275	0.28862813
2.3357215	0.26222164
4.2813324	0.23582942
7.8475997	0.20946402
14.384499	0.18314777
26.366509	0.15691991
48.329302	0.130849
88.586679	0.105722
162.37767	0.079967
297.63514	5.49E-02
545.55948	3.43E-02
1000	2.30E-02

Hydraulic conductivity for saturated soil sample for dam at D-10=0.02 and D-60 =0.3:-

From this analysis it is shows that the as matric section increases the value of volume of water content function increase and the results are compare to these above value are more accurate.

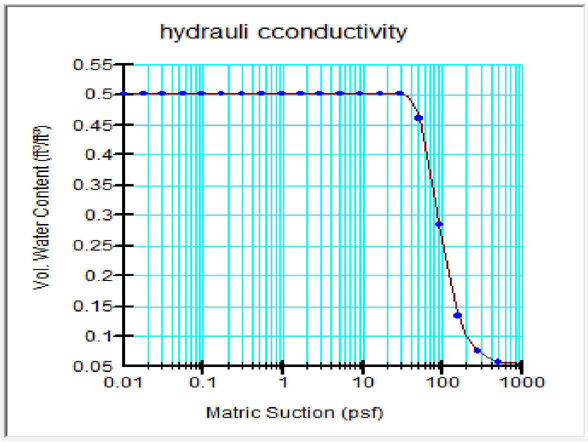

Fig 4.2.3-Hydraulic conductivity at downstream section of dam

4.2.2. Water content function for dam at upstream and downstream section:-

4.2.2.1. Water content function for x-conductivity and pore water pressure:-

Form the graph it is observed that the values of water content are increase at the low water level of dam and the results are clearly more than the hydraulic conductivity function.

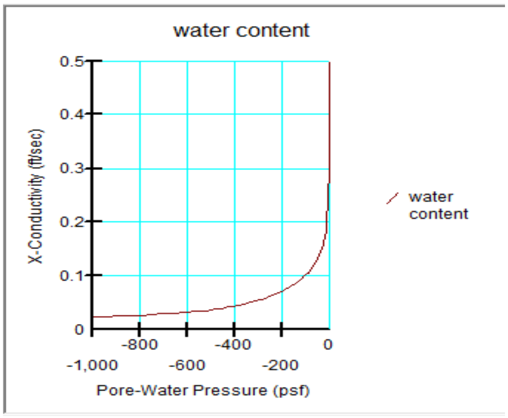

Fig.4.2.4-water content for upstream side of dam

Table 4.2.4 –water content function at upstream section of dam

Estimation method-Van Genuchlen	
Estimate volume water content function	
Saturated wc=0.5ft3/ft3	
ø at 10% passing=0.02	
ø at 60% passing=0.3	
Matric suction(Psf)	VWC(ft3/ft3)
0.01	0.5009978
0.01767316	0.5009978
0.031234059	0.5009978
0.0552	0.5009978
0.0975566	0.5009978
0.1724134	0.5009978
0.30470899	0.5009978
0.53851707	0.5009978
0.95172984	0.5009978
1.6820074	0.5009978
2.9726386	0.5009978
5.2535917	0.5009978
9.2847567	0.5009978
16.409099	0.5009978
29.000064	0.5009977
51.252277	0.45996
90.578969	0.2846
160.08166	0.13412
282.9148	0.0756657
500	0.057528

4.2.2.2. Water content function for slope function and pore water pressure:-

4.2.2.2. Water content function for slope function and pore water pressure:-

Form this it is observed that the values of slope function decreases as the pore water pressure increase and the seepage through the dam decrease for the static pressure head.

Table 4.2.5-water content function at downstream section of dam

Estimation method-Van Genuchlen	
Saturated kx=0.5 ft/sec	
Residual water content=1 ft3/ft3	
Matric suction(Psf)	kt(ft3/ft3)
0.01	0.5
0.01767316	0.499983
0.031234059	0.499945
0.0552	0.499859
0.0975566	0.49966
0.1724134	0.499203

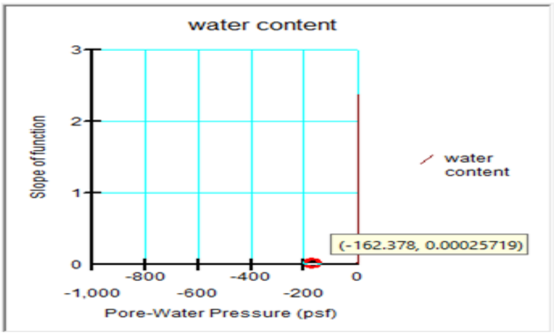

Fig.4.2.5-water content for downstream side of dam

IV. CONCLUSION

In this investigation, the seepage analysis using Geo-studio software gives more accurate results than analytical method.

It is found that the seepage occurs during January to December months for the years from 2001-2016. Therefore, the dam is safe for seepage losses.

The hydraulic conductivity function for different level of dam are found to be satisfactory and water content functions for the seepage loss are found to be accurate as compare to manually calculated seepage loss on the basis of daily reservoir water level form.

It is concluded that the dam is safe against piping and seepage loss through dam body for a particular type of analysis.

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