International Journal of Advances in Engineering and Management (IJAEM)
Volume 3, Issue 10 Oct 2021, pp: 737-742 www.ijaem.net ISSN: 2395-5252

Evaluation of Dadin Kowa Dam Stability Gombe State, Nigeria.

[1]Uloko, Josiah. O., [2]Lagasi, Joseph. E. and [3]Caleb, Bukar. C.
[1]Department of Civil Engineering Technology, Federal Polytechnic, Bauchi, Nigeria.
[2]Department of Civil Engineering Technology, University of Jos, Plateau State, Nigeria.
[3]Rectory Department, Federal Polytechnic, Bauchi, Nigeria.
Corresponding Author: Uloko, Josiah Onu

Submitted: 05-10-2021 Revised: 18-10-2021 Accepted: 20-10-2021

ABSTRACT: Dams are vital elements in any modern society and have great economic values, but they also present a potential risk because thirty five (35) percent of failures in embankment dams have been attributed to internal erosion and seepage. The Dadin Kowa dam being an earth dam was selected as a case study to analysis the seepage via the filter drain and core of the dam using Geo-slope SEEP/W a 2D finite element method based software that can be used to model the dam filter drain and determine the seepage, provided the hydraulic conductivity and boundary conditions data are adequately defined. Analyses were carried out at the maximum pool levels of 50m of three sections of the dam, STA 455, 450 & 425. Results showed that the annual seepage value at 50m maximum pool water level of STA 455 was 7726.32m^3/year, the seepage value is less significant as compared to the dam capacity of 1.77 billion cubic meters. The flow velocity at 50m maximum pool water level obtained was 0.02795x10^{-7} m^3/min where the filter drain was in place but where they are not the value is 2.6977x10^{-7} m/s which is high and water pressure are built around the core of the dam, this excess water seepage from the upstream to downstream area of the dam and leads to the dam collapse and settlement around the downstream area are affected which results to dead and destruction of properties. It is recommended that filter drains be properly designed with adequate dam construction materials and concrete apron be provided at the upstream area of the dam.

KEYWORDS: Earth Dam, Seepage, Filter drain, Geo-slope SEEP/W and Analysis.

I. INTRODUCTION

Throughout history till now there are evidences that mankind has feared and respected the destructive power of water. Especially in the form of heavy rainfall, melted snow, over flooded river banks, tsunamis' wave on open sea, tides and floods. Water is one of the most powerful forces of nature. Hidden in rock crevices and soil pores, it exerts unbelievable force that rip down mountain side, mud slide and destroys engineering works. As a result engineers had long taken importance steps of controlling water on the earth surface and beneath, in pores and cracks of rocks and formations for the benefit of mankind and several engineering project which one of them is the dam. [1]

The building of dams started long time ago. The Sadd-el-kafara Dam, built in Egypt is believed to be the oldest dam in the world. It was built in about 2700 B.C., located on the Nile River about 20 miles south of Cairo. The remains of earth embankment built for diverting water to large community reservoirs can still be found in Sri Lanka and Israel. [2] [3]

Seepage can be defined as the flow of water through homogeneous saturated soil under steady-state conditions. Furthermore, the soil particles, soil structure, and water are assumed incompressible and flow obeys Darcy's law. Also seepage is considered to be all movement of water from the reservoir through the embankment, abutments, and foundation. This includes porous media (inter-granular) flow, flow in fractures, and concentrated flow through "defects" such as cracks, loose lifts, etc.

Most dams have some seepage through or around the embankment as a result of water moving through the soil structure. If the seepage forces are large enough, soil can be eroded from the embankment or foundation. Seepage can also develop behind or beneath concrete spillways or headwalls. The signs of this type of problem could

International Journal of Advances in Engineering and Management (IJAEM)
Volume 3, Issue 10 Oct 2021, pp: 737-742 www.ijaem.net ISSN: 2395-5252

be cracking or heaving. Freezing and thawing will amplify the effects of seepage on concrete structures.

Dadin Kowa dam is selected as the case study for this research work where the climate of Dadin-kowa is characterized by a dry season of six months, alternating with a six months rainy season. The precipitation distribution is mainly triggered by a seasonal shift of the inter-tropical Convergence Zone (ITCZ). The relief of the town ranges between 650 m in the western part to 901 mm in the eastern parts. Dadin-Kowa Dam is a multipurpose dam which impounds a large reservoir of water from Gongola River. It has a storage capacity of 1.77 billion cubic meters. [4]

The maximum flood level is 249 m above sea level (a.s.l), a maximum supply level of 247 m (a.s.l) and minimum supply of 239 m (a.s.l). The surface area of the reservoir is 300 km^2. The 1:10,000 year peak in-flow is 3,160 m^3/sec and the peak outflow is 1,110 m^3/sec. The total catchment area of the Gongola River is approximately 56,000 km^3, 58.5% of which lies upstream of the dam. It also has a gated overflow crest open chute bucket spillway with a maximum design discharge of 1,110 m/sec at reservoir maximum flood level and three (3) radial gates. [5]

The finite element is conceptually a physical rather than a mathematical approximation. The flow region is subdivided into a number of elements and permeability are specified for each element. Boundary conditions are specified in term of heads and flow rates and a system of equations is solved to compute gradients and velocities in each element [6] [7].

Two- and three-dimensional finite element seepage computer programs for both confined and unconfined flow problems have been developed. Steady-state and transient problems can be solved. Darcy's law can be used to describe water flow through soils in both saturated and unsaturated conditions [8] which can be stated as follows:

$$q = - ki \qquad \text{--(1)}$$

Where: q = discharge per unit area, i= total head gradient and k = co-efficient of permeability.

The governing partial differential equation for seepage through a heterogeneous, anisotropic, saturated, unsaturated soil can be derived by satisfying conservation of mass for a representative elemental volume. If the assumption is made that the total stress remains constant during a transient process, the differential equation can be written as follows for the three dimensional transient case:

$$\frac{\partial}{\partial x}\left(k_x \frac{\partial h}{\partial x}\right) + \frac{\partial}{\partial y}\left(k_y \frac{\partial h}{\partial y}\right) + \frac{\partial}{\partial z}\left(k_z \frac{\partial h}{\partial z}\right) = m\gamma\left(\frac{\partial h}{\partial t}\right) \qquad \text{---(2)}$$

Where,

K_x, $K_y$and $K_z$are co-efficient of permeability of soil in x, y and z direction, respectively, and m = water storage. [9]

Darcy Law shows the direct proportion relationship between the seepage velocity and the hydraulic gradient and the character of earth will influence it in uniform porous medium. The normal form of Darcy Law is as follows:

$$u = -K\frac{dH}{ds} \qquad \text{--(3)}$$

Where: u is the seepage velocity ,K is the permeability coefficient and H is the piezometric head on corresponding point.

This is the summation for pressure head and the location altitude. Because of the linear relation, Darcy Law is adequate to the laminar flow with linear drag force, excepting the turbulence seepage in big pore like rock filled dam, most seepage can be defined as laminar flow, that why the Darcy Law is applied so widely.

Software use in handling seepage has gone a long way in simplifying the analysis of seepage in dam. ANNs have been recently employed for the solution of many hydrologic, hydraulic and water resources problems ranging from rainfall and runoff [10] to sediment transport [11] to dispersion. Depending on the modeling approach, different mathematical models are possible for tackling the same problem [12]. Out of various available numerical techniques, finite difference method (FDM), finite element method (FEM), finite volume method (FVM), boundary element method (BEM) and meshless method have become more popular among scientists and engineers.

Several approaches can be used to transform the physical formulation of the problem to its finite element discrete analogue. If the physical formulation of the problem is known as a differential equation then the most popular method of its finite element formulation is the Galerkin method [13].

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 is a finite element CAD software product for analyzing groundwater seepage and excess pore-water pressure dissipation problems within porous materials such as soil and rock. [14]

The aim of this paper is to investigate flow velocity of the seepage water by the filter drain, through Dadin Kowa dam using the Geo-

International Journal of Advances in Engineering and Management (IJAEM)
Volume 3, Issue 10 Oct 2021, pp: 737-742 www.ijaem.net ISSN: 2395-5252

slope 2D SEEP/W FEM Software and Dadin Kowa dam in Gombe state, Nigeria as a case study. The results expected are graphical views of the software values of the flow velocity for the filter drain in place and where it is not.

II EXPERIMENTATION

Location of Dam

The dam is located at 37 km from Gombe town and 5 km North of Dadin Kowa village in Yamatu-Deba L.G.A of Gombe state. (Between latitude 10° 19' 19’’N and longitude 11° 28' 54’’E). Dadinkowa dam is a source of water for the irrigation of Dadinkowa Dam has the potential of irrigating 44,000 hectares of land, comprising of Dadinkowa and Guyuk lots and rural water supply for domestic use.

The dam is an Earth and Rock fill ($1x10^6$ m^3), whose height is 42 meters above deepest foundation. The dam length is 520 meters, width of crest is 8 meters while the width of the base is approximately 230 meters.

Material data required:

Data used were collected from Upper Benue River Basin Development Authority (UBRBDA) office, based in Dadin Kowa town, Gombe State. The Soil data are the logged ones during construction of dam.

Number of Cases Considered for Analysis.

Three different cases were considered so as to have a general view of the seepage at those sections, and check the trend of seepage flow. The depth of the sections also differs and the boundary conditions at each upper stream of the dam sections considered are not the same.

Typical Sections of Area Considered.

Three sections of the Dam as listed below were selected for the analysis which are:

1. Section STA. 455 (Maximum dam section), 2. Section STA 450 3. Section STA 425.

The general details of the dam foundation and sections are shown in plate 1.

Software for the Analysis

The analysis was carried out using a computer programme SEEP/W (2007), software developed by GEO-SLOPE limited of Alberta, Canada. 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 is a finite element CAD software product for analyzing groundwater seepage and excess pore-water pressure dissipation problems within porous materials such as soil and rock.

Region Property hydraulic conductivity and Cross Section

Regional properties for the selected sections of the Dadin Kowa dam, are presented in Table 1 while that of the Cross section are on Table 2. [15]

Mesh Size and Option

A global element size of 3.5 m was adopted and the triangular element mesh pattern used was the triangle because of the geometric nature of the dam.

III TEST RESULTS

The results of the analysis are presented in Figure 2 to 4 which is the graphic views of the filter drain with and without.

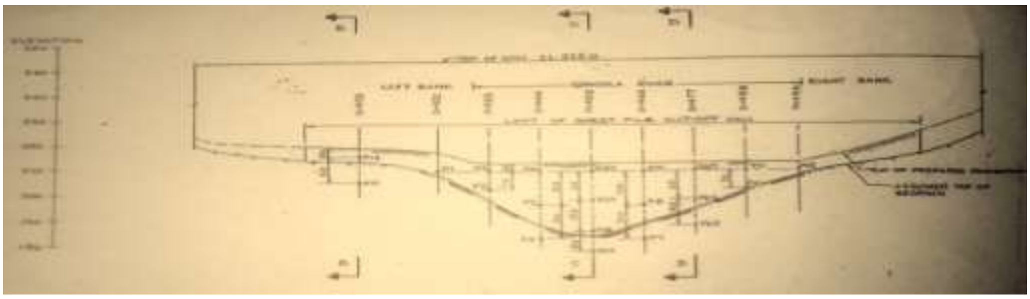

Plate 1. Dam Section Showing details of Dam Foundation. (Source UBRBDA)

Table 1: Region Property

S/N	Region Property		Hydraulic Conductivity
1	Foundation		$1x10^{-5}$ m/s
2	Bedrock		$1x10^{-8}$ m/s

International Journal of Advances in Engineering and Management (IJAEM)
Volume 3, Issue 10 Oct 2021, pp: 737-742 www.ijaem.net ISSN: 2395-5252

3	Shell		1x10^{-5} m/s
4	Core		1x10^{-8} m/s
5	Filter blanket		1x10^{-4} m/s
6	Cutoff wall		1x10^{-8} m/s

Source: Tectonic Engineering & Consult Ltd, (2011).

Table 2: Typical Cross Section of Dadin Kowa Dam

Dam section	Dimensions (meters)
Dam crest elevation	252
Dam crest width	8
Maximum floor level	249
Maximum reservoir level	247
Minimum reservoir level	239
Upstream slope	2.5:1
Downstream slope	2.2:1
Reservoir volume	1,770 million cubic meters

Source: Tectonic Engineering & Consult Ltd. (2011)

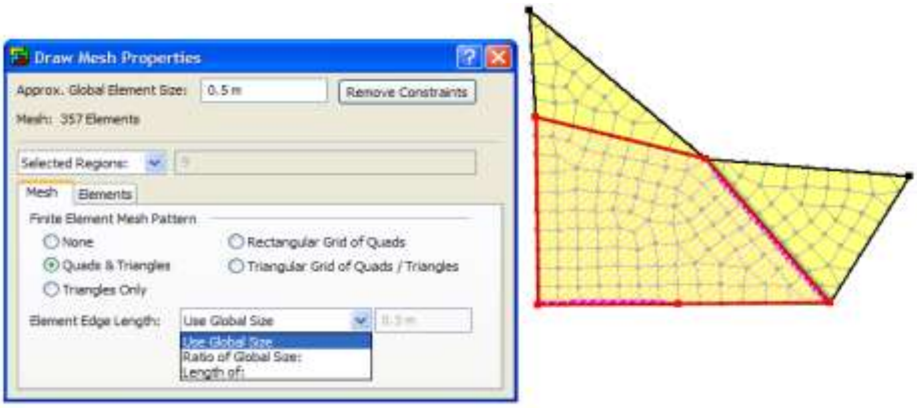

Figure 1.DrawMeshPropertiesoptions (Source: SEEP/W software guideline)

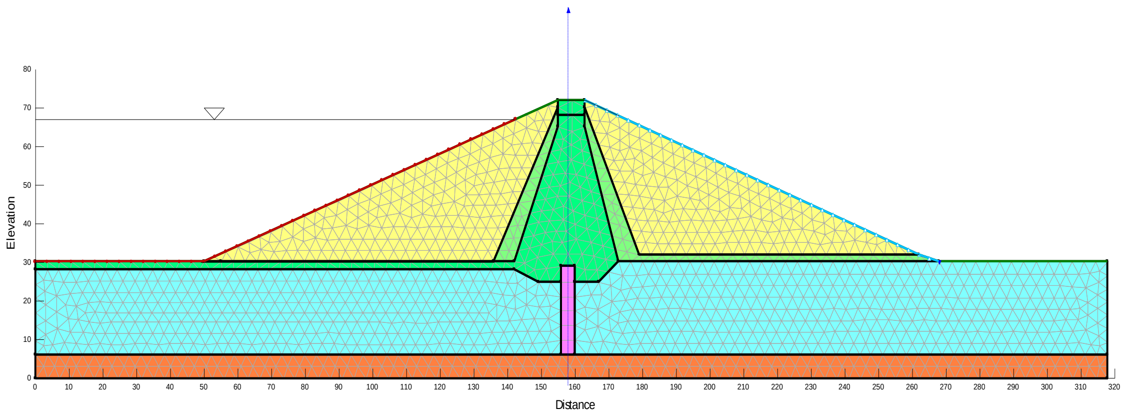

Figure 2. Section 450 Steady-state analysis definition (at maximum pool) 50m upstream and downstream.

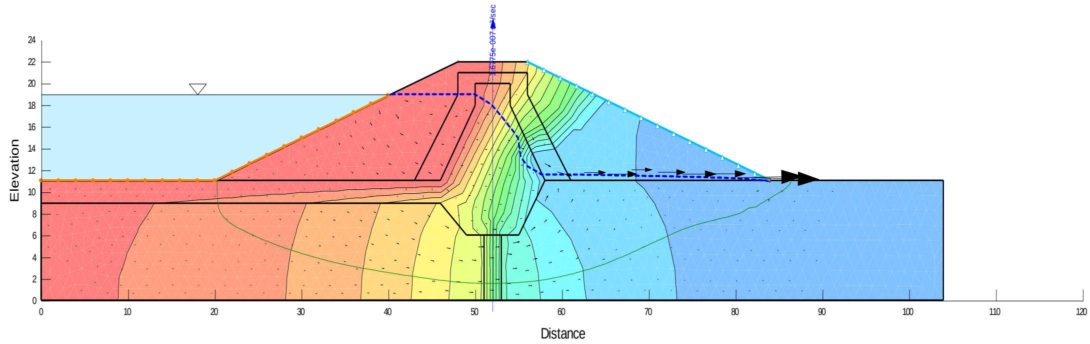

Figure 3. Section 450 Steady-state analysis solution contour (at maximum pool) with filter drain in place.

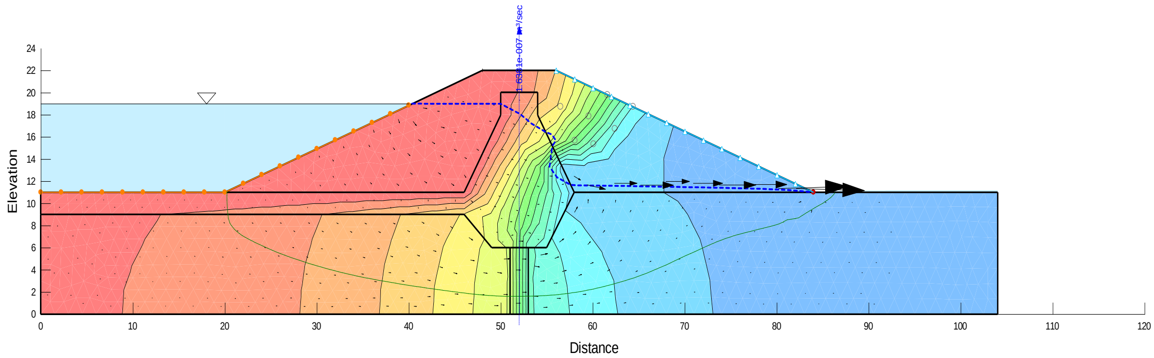

Figure 4. Section 450 Steady-state analysis solution contour (at maximum pool) without filter drain in place.

IV OBERSERVATION FROM THE TEST

Values obtained with the Geo-slope SEEP/W software used to run the analyses and as obtained particularly for the dam at 50mm pool level STA 450 values obtained are:Average maximum flow velocity value of $0.02795x10^{-7}$ m^3/min was recorded with the filter drain in place but where they are not in place the value of $2.6977x10^{-7}$ m/s was recorded which is high and keep building as the water raise and affects the core due to water pressure and can lead to dam failure.

V. CONCLUSION

The Dadin Kowa dam was selected as a case study to analysis the seepage using Geo-slope SEEP/W a 2D finite element method based software that can be used to model and determine seepage, provided the hydraulic conductivity and boundary conditions are adequately defined. Analysis were carried out at the maximum pool levels of three sections of the dam, STA 455, STA 450 and STA 425. [16]

The flow velocity at 50m maximum pool water level obtained was $0.02795x10^{-7}$ m^3/min where the filter drain were in place but where they are not the value is $2.6977x10^{-7}$ m/s which is high and water pressure are built around the core of the dam, this excess water seepage from the upstream to downstream area of the dam and leads to the dam collapse and settlement around the downstream area are affected which results to dead and destruction of properties. It is recommended that filter drains be properly designed with adequate dam construction materials and concrete apron be provided at the upstream area of the dam.

Most dams with instrumentations keeps records of the dam behavior by monitoring it through the install instrumentations, but when they are affected or not working properly it becomes difficult to get the required data as required. This research work provides insight to the use of Geo-slope SEEP/W 2D of finite element method software in analyzing seepage of Dadin Kowa dam and give vivid details of the filter graphical views and can be easily read and interpreted and more so be used to check dam's seepage values, pore water pressure and flow pattern and can be used by the engineers responsible for the dam operation.

Dadin Kowa Dam filter drain is in place and the results shows that the dam is stable in other words the filter drain is functional, time to time checks on the drain will help to maintain stability.

REFERENCES

[1] Uloko, J.O (2016), Seepage Analysis of Dadin Kowa dam using 2D Finite Element Method, unpublish thesis.

[2] Schnitter, N. J. (1994). A History of Dams; the Useful Pyramids. Oregon,Books News Inc.
[3] McCully P. (1996). Silenced Rivers: the Ecology and Politics of Large Dams, London, Zed Books.
[4] Ibeje, A. O & Okoro, B.C (2013). Short-term forecasting of Dadin Kowa Reservoir in-flow using Artificial Neural Network. (International Journal of Engineering and science) 6, 63-73.
[5] Chido-Amajuoyi, G.U. & Ofoegbu, G.I. (1987). An analysis of water pressure and deformation data for Dadin Kowa Dam. 9th Regional Conference for Africa on Soil Mechanics and Foundation Engineering, September, 1987.
[6] Desai, C.S. (1972). Theory and application of the finite element method in GeotechnicalEngineering. In C.S. Desai (Ed.), A symposium conducted at the meeting of the U.S. Army engineer water ways experiment station Vicksburg (pp 3-90).
[7] Desai, C.S. (1977). Flow through porous media. In C.S. Desai & J.T. Christian (Eds.); Numerical Methods in Geotechnical Engineering. Vol 3 (pp 458-505). New York, McGraw-Hill.
[8] Richards, L.A. (1931). Capillary conduction condition of liquids through porous mediums. Physics, 9(1), 8-9.
[9] Zhao, W. (2006). An FDM Modeling to compute the seepage field for fill dam (Miscellaneous Paper pp 831-835).
[10] Rajurkar, M.P., Kothyari, U.C. &Chaube, U.C. (2002). Artificial neutral networks for daily rainfall - run off modeling. Hydrology Science Journal 47(6), 865- 878.
[11] Tayfur, G. (2002). Artificial neutral networks for sheet sediment transport. Hydro Sciences Journal. **47**(6): 879-892.
[12] Snehal, P.A., Shekhar, D. &Bhole. (2011). Application of FEM in Civil Engineering Applications, International Journal of Earth Sciences and Engineering, 4 (6) SPL, 748-751.
[13] Najim O. Salim AL- Gazali. The Finite Element Model for Seepage Flow through AL-Adheem Dam. (MSc. Thesis, College of Engineering, University of Babylon, 2008).
[14] Geo-slope (2007). **SEEP/W software user guide. Geo-slope international Ltd.,Canada.**
[15] Inspection, Monitoring and Evaluation Services of Dadin Kowa dam. (2011) Technical analysis report by Tectonic Engineering & Consult Ltd (TECL).
[16] Upper Niger River Basin Development Authority. (1988).**Development maps.**