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Estimation of Seepage for Ajdabya Reservoir by Moderation Multiple Regression

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Abstract

Seepage is the main cause of failure of earthen dams; to prevent this failure, excessive seepage problems should be controlled. In this study, lowest seepage quantity through homogenous earth dam with horizontal filter by different methods was estimated. SEEP/W program code was used to investigate 64 models with compute seepage discharge through the dam for the different water depths 8,7,6,5 meters. With different hydraulic conductivity coefficient ranging between 0.000001 to 0.0001. Using different values for each of the above effecting variables on the quantity of seepage. Results showed that The exceptions of the future seepage through the body of the dam has been studied of by using Statistical methods such as Moderating Multiple Regression (MMR).The quantity of seepage predicted by MRR compared with obtained seepage rates from SEEP/W has (R^2 = 0.985, 0.688, 0.689, 0.712) at depths of 5,6,7,8 m, respectively, than the nonlinear empirical equations found in SPSS.

Keywords:Seepage,SEEP,W,MMR,SPSS20,Horizontal filter

* INTRODUCTION

Earth dams are important structures used as artificial reservoirs consists from impervious compacted layers of soils for its core and permeable materials on their upstream and downstream faces to be safe against sliding and overturning forces. Seepage is the quantity of water through an earth dam starts from upstream of the reservoir level to the downstream toe of the dam. The upper surface of this stream of percolating water is known as the phreatic surface (Singh, 1996).[1] For the purpose of controlling this phenomenon in the dam, different types of filters should be designed. The Laplace equation which governs water seepage cannot be solved analytically, except for cases with very simple and special boundary conditions. In the literature reviews, the numerical example that proposed equations is simple to use; hence the designers may find these equations as an additional check to their design by the conventional flow net method (Irzooki, 2016).[2] Seepage and Stability of earth dam were analyzed Using Ansys and GeoStudio Softwares, the significant difference of two programs is related to safety factor deducted that Ansys answer is more acceptable (Kamanbedast and Delvari,2012).[3]The other investigation performed the numerical simulation to find the effect of horizontal drain length and cutoff wall on seepage and uplift pressure in heterogeneous earth dam(Mansuri and Salmasi, 2013).[4]

The case study on "Hub" earthen dam located on (Karachi city-Pakistan) also investigated. SEEP/W simulation compared with field observations for seepage analysis. Calibration of the material properties is made on the basis of minimization of error while comparing observed hydraulic heads with the simulated ones (Arshad and Babar, 2014).[5] Alnealy and Alghazali (2015) analyzed of seepage under hydraulic structures using Slide program. Single and multi- layers soils and its effect on structures with inclined cut-off were studied.

Mamand,(2020)
assumptions were analyzed to estimate seepage through homogeneous earth dam without filter.[6] Çalamak, M., Bingöl, A. N., & Yanmaz, (2016) investigated the suitability and the effectiveness of blanket and chimney drains in earth fill dams for various properties of the drainage system.[7] Irzooki,(2016) was

used SEEP/W code to run on homogenous earth dam models with horizontal toe drain, a new equation was found for computing the quantity of seepage.[2]

Reviewed on effects and control of seepage through earth-fill dams. San Luis dam used to evaluate the unsaturated and transient seepage analysis in which pore-water pressures at failure and progression of the phreatic surface through the fine-grained core for drawdown stability analyses (Li& Bricker, 2019).[8]

*** CURRENT STATE of RESERVOIR**

The Ajdabiya dam is an earth-fill dam with a slope. It was constructed by the Libya government at a location about 20 km south-east of Ajdabiya city.The storage volume in the reservoir is 4.000.000 m3 per day at the maximum level of 98.4 m (about mean sea level) and a minimum of 91.92 m. The ultimate in- flow was given as 3.680.000 m3 per day , but it was safe for 4.500.000 m3 per day, The reservoir has no natural catchment and contained by a circular embankment of diameter 923.2 m to the inner crest. The reservoir operating rang is 6.48 m Great Man- made River. (Nov. 2008). [9]

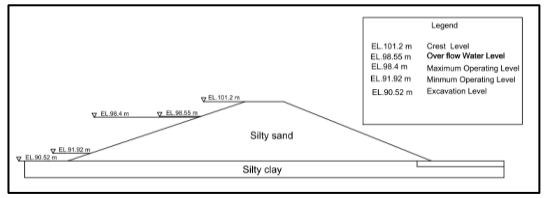


Fig. 1 Current State of the Dam (GMR, 2008).

*** METHODOLOGY OF THE STUDY**

We have done studies by Seep/W software about the saturated and unsaturated flow for the steady- state conditions at the upstream of the horizontal homogeneous earth dam. In this research by Seep/W software we have compute seepage discharge through the dam for the different water depths 8,7,6,5 meters. with different hydraulic conductivity coefficient ranging between 0.000001 to 0.0001 with two slopes of 1/3 and 1/2.5. Using different values for each of the above effecting variables on the quantity of seepage, the conducted cases of the different conductivity and water heights were 64 run.

The boundary conditions for the seepage analysis and the finite element mesh are presented in Figure 2. The elements used to mesh the dam and other parts in the FEM models were quad and triangle shapes. The number of elements and nodes used in the main model is 3114 and 3282, respectively. The boundary condition for the seepage analysis in the steady state is specified as the total head on the upstream and downstream sides.

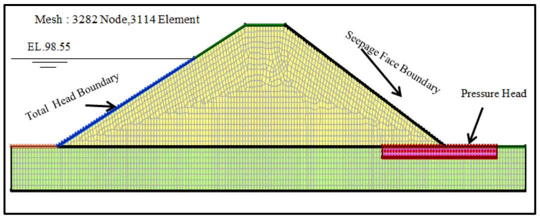


Fig. 2 Location of the boundary conditions

* RESULTS SEEP/W SOFTWARE

The results of the software were sampled in next tables for values of K=0.0001

Table1. Variation of Variables in Hydraulic Conductivity k= 0.0001 and Depths

Depth	*q* (m3/day)		*p* (kpa)		*i*		*v* (m/s)	
(m)	Max	Min	Max	Min	Max	Min	Max	Min
8	0.1934	0.0063	78.46	67.32	0.48	0.16	4.30×10^{-5}	1.46×10^{-5}
7	0.1728	0.0055	68.65	58.13	0.45	0.15	4.10×10^{-5}	1.38×10^{-5}
6	0.1507	0.0048	57.29	49.67	0.39	0.13	3.57×10^{-5}	1.20×10^{-5}
5	0.1285	0.0041	45.67	38.81	0.34	0.12	3.11×10^{-5}	1.05×10^{-5}

Dimensional Analysis:-

Dimensional analysis proves to be a generally valid method to recognize the information structure in the relationships between physical quantities in a precise and clear way. It starts from the fact that in quantitative natural science the descriptive quantities, it has dimensions and can be divided correspondingly into basic quantities and derived quantities.

In this study, a dimensional analysis was applied to predict an empirical equation for determining the seepage quantity through homogenous earth dams with horizontal drain, as shown in Figure 3.From this figure, the possible variables affecting quantity of seepage per unit width (q) are:

q = f (p, , i ,d, D) (1)

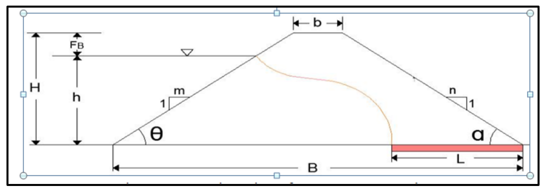


Fig. 3 General Section of Earth Dam

* STATISTICAL ANALYSIS RESULTS

In order to develop an empirical equation that can be used to measure the quantity of seepage through homogenous earth dams with horizontal toe drain, a statistical analysis was carried out using the resulted data of the parameters with SPSS.ver.20 program. The data were arranged ascending and then these data were used in the program.

*** MODERATING MULTIPLE REGRESSION (or MMR)**

In this section, the amount of seepage through dam discharge was specified with several depths, the distance in dam is likely to be shaped by certain moderating factor. Therefore, a moderating variable (MV) may modifies the original relationship between pressure (or p) and hydraulic gradient (or i) factors. The aim of this section is to examine influence of a linear combination of pressure and hydraulic gradient through moderating variable (distance or d) on the quality variable (or q) as dependent variable (DV). Moderation effects are tested with multiple regression analysis, where all independent variables (IV's) and each moderating factor to separate models to estimate and improve the interpretation of regression coefficients. The next following sub-sections discuss the results related to the effect of distance factor on the relationship between pressure and hydraulic gradient factors.

A moderator is a variable that specifies conditions under which a given predictor is related to an outcome. The moderator explains 'when' a DV and IV are related. Moderation implied an interaction effect, where introducing a moderating variable changes the direction or magnitude of the relationship between two variables. A moderation effect could be:-

(a) Enhancing, where increasing the moderator would increase the effect of the predictor (IV) on the outcome (DV);

(b) Buffering, where increasing the moderator would decrease the effect of the predictor on the outcome; or

(c) Antagonistic, where increasing the moderator would reverse the effect of the predictor on the outcome.

Moderating multiple regression was performed to assess the effects of a moderating variable. To test moderation, we will in particular be looking at the interaction effect between X and M and whether or not such an effect is significant in predicting Y.

*** Moderating Effects of Distance factor in Depth:**

It was assumed the relationship between pressure and hydraulic gradient is modified by distance factor on quality as dependent variable in depths. This assumption was explored in the following hypothesis:

H : There is interaction effects of pressure and hydraulic gradient factors through distance variable on quality variable in depth. To meet the objective and to find out the effect of pressure and hydraulic gradient factors through moderating effect of distance on the quality variable, which can be modeled as follows:-

$Y= \beta_0 + \beta_1 X_1 + \beta_2 X_2 + Z\ (\beta_3+\beta_4 X_1 + \beta_5 X_2) + e$

Based on the above model the effect of pressure and hydraulic gradient factors through moderating effect of distance on the quality variable was evaluated using the model outlined below:

Where,

Y = quality variable (seepage or q);

β_0 = is the intercept;

$\beta_{i\ (i=1,\dots,5)}$ = the coefficients regression;

X_1 = pressure (or p);

X_2 = hydraulic gradient (or i);

Z = the moderating variable (distance or d).

e = is a residual term.

*** PROCEDURE OF RUNNING SPSS PROGRAM**

Based on the above model the effect of pressure and hydraulic gradient factors through moderating effect of distance on the q Through two models, model 1 which includes (2) the mediating variable and model 2 without the mediating variable quality variable was evaluated using the model outlined below for depths 5,6,7,8 m, Through two models, model 1 which includes the moderating variable and model 2 without the moderating variable.

Table 2. Summary of Models in Depths 5,6,7,8

Depths (m)	Model	R	R^2	Adjusted R Square	Std. Error of the Estimate	Durbin-Watson
5	1	.806	.649	.637	.138	
	2	.994	.987	.985	.026	1.661
6	1	.806	.649	.637	.137	
	2	.839	.704	.688	.127	1.532
7	1	.807	.651	.639	.1356	
	2	.839	.705	.689	.1261	1.516
8	1	.805	.649	.636	.1354	
	2	.844	.712	.697	.1236	1.540

a. Predictors: (Constant), i, p

b. Predictors: (Constant), i, p, d

c. Dependent Variable: q

Table 2. Shows model 1 and 2 summary for depths:-

1- In depth 5 as can be seen, the variation explained of the predictors: pressure and hydraulic gradient by model 2 with R^2 = 0.987 (adjusted R^2 =0.985) is more than that variation explained by model 1 with R^2 = 0.649 (adjusted R^2 =0.637). The percentage increase in the variation explained in adjusted R^2 by model 2 is 54.6%. The moderating factor entered makes substantial contribution to overall model fit.

2- In depth 6 as can be seen, the variation explained of the predictors: pressure and hydraulic gradient by model 2 with R^2 = 0.704 (adjusted R^2 =0.688) is more than that variation explained by model 1 with R^2 = 0.806 (adjusted R^2 =0.637). The percentage increase in the variation explained in adjusted R^2 by model 2 is 8.0%. The moderating factor entered makes small contribution to overall model fit.

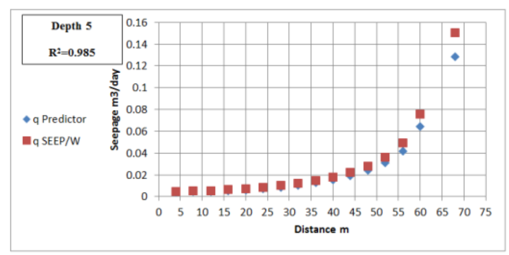
3- In depth 7 as can be seen, the variation explained of the predictors: pressure and hydraulic gradient by model 2 with R^2 = 0.705 (adjusted R^2 =0.689) is more than that variation explained by model 1 with R^2 = 0.807 (adjusted R^2 =0.651). The percentage increase in the variation explained in adjusted R^2 by model 2 is 8.0%. The moderating factor entered makes small contribution to overall model fit.

4- In depth 8 as can be seen, the variation explained of the predictors: pressure and hydraulic gradient by model 2 with R^2 = 0.844 (adjusted R^2 =0.712) is more than that variation explained by model 1 with R^2 = 0.805 (adjusted R^2 =0.649). The percentage increase in the variation explained in adjusted R^2 by model 2 is 9.6%. The moderating factor entered makes small contribution to overall model fit.

Table 2. Also shows that the Durbin-Watson statistic is a test to detect autocorrelation (homoscedasticity) in the residuals. A value within the range of 1 to 3 means that there is no autocorrelation detected in the sample, and therefore no inter-item correlation. The results of the coefficients for model 2 in depths 5,6,7,8 m are shown in Table 3 and Comparison of Seepage Quantities between Moderate Multiple Regression Model and Seep/w in Depth s

Table 3. Moderate Multiple Regression Model 2

Model		Unstandardized Coefficients		Standardized Coefficients	T	p-value
		B	Std. Error	Beta		
Depth 5	(Constant)	-.472	.048		-9.929	.187
	p	.009	.001	.283	9.893	.000
	i	.037	.067	.110	2.550	.046
	D	.008	.000	1.216	38.814	.000
Depth 6	(Constant)	-1.295	.766		-1.690	.097
	p	.021	.012	.748	2.796	.040
	i	.473	.300	.149	2.578	.046
	D	.039	.012	1.473	3.215	.002
Depth7	(Constant)	-1.320	.779		-1.694	.096
	p	.018	.011	.780	2.715	.041
	i	.376	.265	.136	2.416	.045
	D	.040	.013	1.512	3.177	.002
Depth8	(Constant)	-1.550	.777		-1.996	.051
	p	.019	.009	.887	2.619	.047
	i	.308	.231	.127	2.333	.049
	D	.043	.012	1.619	3.521	.001



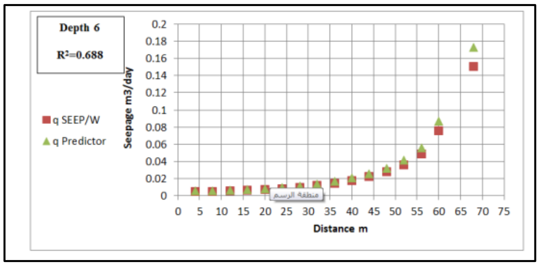
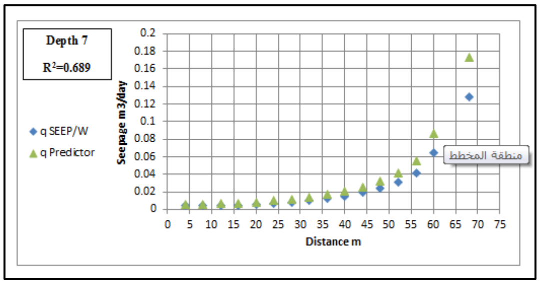


Fig. 4 Comparison of Depth 5

Fig. 5 Comparison of Depth 6



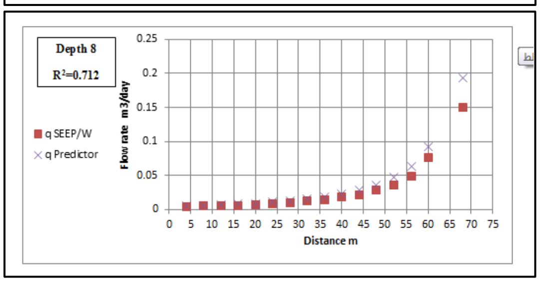


Fig. 6 Comparison of Depth 7

Fig. 7 Comparison of Depth 8

The models have been fit, predicted and residual values are usually calculated. The predicted values are calculated from the estimated regression equation; the raw residuals are ten other forms of residuals are used for model diagnostics, such as cumulative residuals. Some procedures can calculate standard errors of residuals, predicted mean values, and individual predicted values.

* CONCLUSIONS

The In the study , the characteristics of seepage through homogenous earth dams with horizontal toe drain were studied using results which obtained from running the SEEP/W program on different geometries of dams. Based on the results and analysis, the following conclusions can be summarized**:-**

1- The seepage quantity through homogenous earth dams increased with increasing the depth. Also, the seepage quantity increased with increasing the height of upstream water depth and the length of horizontal toe drain**.**

2-The seepage through earth dams increasing with increasing the hydraulic conductivity coefficient.

3- MRR method shows The median variable distance has a significant effect on the accuracy of the equation geometrical variable on the seepage discharge.

4-The exudation rates measured by SEEP/W were compared with the amount achieved by MRR. This relationship gave higher determination coefficients (R^2 = 0.985, 0.688, 0.689, 0.712) at depths of 5,6,7,8 m,respectively,than the nonlinear empirical equations found in SPSS.

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