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Investigation and Estimation of Seepage Discharge Through Homogenous Earth Dam with Core by Using SEEP/W Model and Artificial Neural Network

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Abstract

This paper concerns to investigate the amount of seepage through the homogenous earth dam with core by finite elements software SEEP/W. By SEEP/W investigates groups were executed with three different upstream and down.stream slopes of earth dam, four different upstream and downstream slopes of core, for homogenous cases. For each run the amount of seepage discharge was specified. Dimensional analysis was used for the product and with aiding of the SPSS statically program to advancement an empirical equation in order to estimate the amount of seepage discharge through the homogenous earth dam with core resting on impervious base. In addition using ANN the SEEP/W results and the recommended equation in this paper have been verified, which show great agreement with SEEP/W results with using one hidden layer for ANN.

Keywords: ANN, Earth Dam, FEM, Seepage.

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1.Introduction

Earth dams will leak to some amount and seepage only becomes a problematic if it endangers the embankment either by helping erosion in the downstream dam or by causing water logging of the earth dam and thus affecting its stability [1]. The water seeping from the downstream face of any dam is a cause of concern, as finer materials are eroded and carried out of the embankment, this could lead to slumping or piping in the earth dam structure. So design of any core or cutoff within the embankment and the use of a filter to collect and safely channel seepage water in the downstream of earth dam will keep the dam safety from the seepage effect [1]. For the SEEP/W is a finite element software product that models both saturated and unsaturated flow and simulate the real physical process of water flowing through a particulate medium [2]. Many researcher study seepage problem through earth dam, Foad et al, (2011) using multi-layer perceptron network (MLP), radial basis function network (RBF) and finite element method (FEM) to estimating differences in permeability of earth dam body during seepage occurrence [3]. Joghataie et al, (2012), using neural network model for dam reservoir foundation to study earthquake loading for nonlinear hysteretic of concrete gravity dams [4]. Roshani et al, (2012), using finite element method and artificial neural network (ANN) to estimate the seepage volume through the dam core and encounters the costs concerning to the volume of earth works [5]. Baghalian et al, (2012), estimation and analysis of seepage discharge in and piezometric head under the dam using neural network model and compared it with actual data [6]. Nourani et al. (2012), using single (ANN) with three-layered Perceptron model for analysis earth dams seepage and piezometers at different cross sections of the dam [7]. Kokaneh et al. (2013), used neural network and a Finite element method (FEM) by SEEP/W software to estimate seepage discharge through and under ‘Fealeh Khase’ dam [8]. Kareem et al. (2013), studied the stability and infiltration of the earth dams [9]. Fattah et al. (2014), analysis seepage for zoned earth dam by finite elements analyzed using the software package (SEEP/W) taking effect of the permeability, shell material, core location and thickness [10]. Asadi et al, (2014), analysis Seepage in body and foundation of dam using (SEEP/W-2D) software and (SEEP/3D) by Plaxis, where the actual topography modeled of dam considering actual permeability and faults measured at foundation, right, left abutment, geotechnical data and permeability coefficient tests [11]. Xue et al, (2014), using the technique regression neural network (GRNN) to approximating piping possible in earth dams and levees [12]. Sakhmarsi et al, (2014), using (SEEP/W) to studied the effect of different conditions cutoff wall position, depth and permeability on the seepage discharge and outlet gradient of homogeneous earth fill dams [13]. Arshad et al. (2014), comparison depending on (SEEP/W) models and field notes for seepage analysis exit gradient and maximum seepage velocity through and under body an earth dam [14]. Melih (2014), investigated steady state and transient seepage through earth fill dams using finite element software (SEEP/W) [15]. Abdulkadir et al, (2015), used neural network model for estimating reservoir storage for dam [16]. Athani et al, (2015) using finite element method analyses seepage (steady state and transient) and stability of earth dam [17]. Mortazavi et al. (2015), analysis leakage, hydraulic gradient in dams using (3D-SEEP), (SEEP/W) by using water withdrawal place from the body [18]. Karampoor et al. (2015), study using (SEEP/W) Model the effect of clay core in seepage from non-homogenous earth dams [19]. Jamel, (2016), estimate the quantity of seepage through homogenous earth dam without filter using (SEEP/W) model verify with artificial neural network (ANN), and compare with Casagrande's solution and Dupuit's solution [20]. Ehsani, et al, (2016) developing a neural network reservoir process system suitable for use in large-scale hydrological to understanding of the broad effects of dams operation [21].

The present paper analysis and estimating the seepage through homogenous earth dam with core resting on impervious base using different parameter for each of dam and core using the software program (SEEP/W) which is a sub-software of Geo-studio geotechnical program, then using of dimensional analysis for the system tryout of (SEEP/W) output, and using software (SPSS) Statistics to determine general equation that estimate the quantity of seepage through earth dam with core, and for verifying these results with artificial neural network (ANN) using one and two hidden layer for (MLPs) algorithms, also to determine importance ratio of each research parameter on the quantity of seepage.

2.Procedure of Setup

For the intend of operation SEEP/W model tests using three groups (A, B and C) of upstream slopes of earth dam which are (1:3, 1:2.25, 1:2.5) respectively, for each variable groups using three different downstream slopes (1:2.5, 1:2.25, 1:2), also four different upstream slopes of core (1:1, 1:0.75 ,1:0.5 ,90°) and downstream slopes of core (1:1, 1:0.75 ,1:0.5 ,90°). All above are with constant variable of permeability for earth dam (ke= 0.0001m/sec), core permeability ($kc = 1 * 10^{-6}$ m/sec), upstream head (h=30m), top width of earth dam and core (b=10m), and height of earth dam and core (H=35m). so the overall runs were carried out are (144) runs. For each run set the quantity of the seepage outflowing through homogenous earth dam with core resting on impervious base. Figure 1 show the groups designation for model tests. Also Figure 2 show the mash properties for one example model.

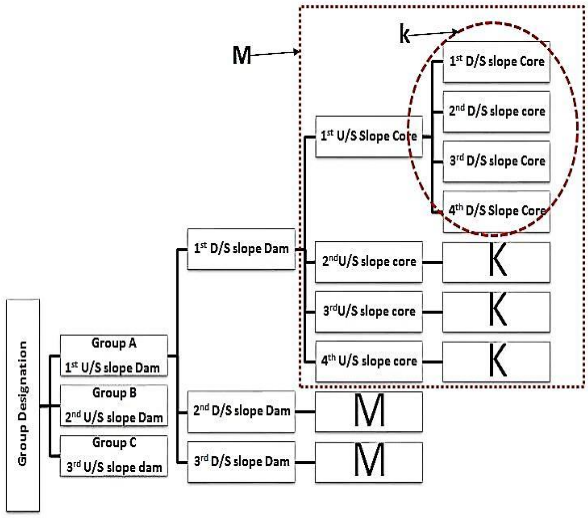

Figure 1: The groups designation for model tests

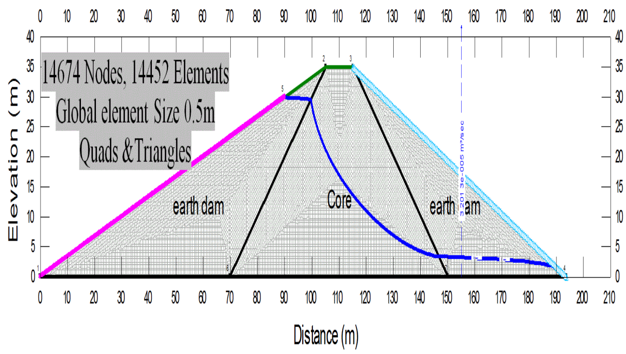

Figure 2: General Mash properties of homogenous earth dam with core

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3. Dimensional analysis

Dimensional analysis agreements a method for decreasing complex physical problems to the simplest form prior to obtaining a measurable answer. It is mainly useful for: presenting and interpreting investigational data, confronting problems not responsive to a direct theoretical solution, checking equations, establishing the comparative importance of physical modeling and particular physical phenomena [22].

A dimensional analysis is functional so as to progress an empirical equation to set the quantity of seepage running through homogenous earth dam with core resting on impervious base.

Figure 3 show the potential variables that can be influence on the seepage quantity in to the body of earth dam containing core in it:

q= f (sin (U/S Dam), sin (D/S Dam), sin (U/S Core), sin (D/S Core), Ke , Kc, H, h, B, bc , b) (1)

By π theorem, the subsequent dimensionless terms may be obtained from the above equation.

(q/K_cB)= f (sin (U/S Dam), sin (D/S Dam), sin (U/S Core), sin (D/S Core), Ke/ Kc, bc /B, b/B, H/B, h/B) (2)

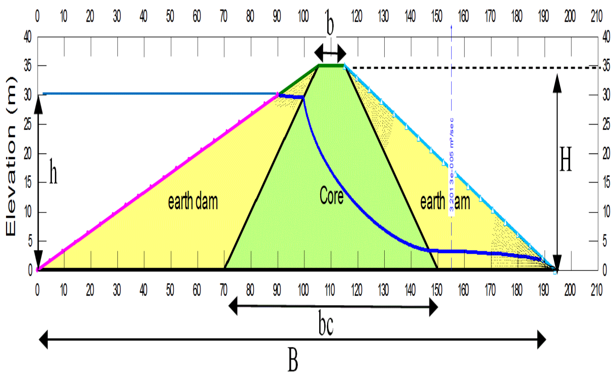

Figure (3): The general section of homogenous earth dam with core

4. Results and Discussion

4.1 Relatives Between the Variables of Earth Dam with Core

Using (SEEP/W) records, the following relatives between the variables for the left side of the equation 2 with every variable in the right side of the equation were found.

Figure 4 shows the connection between the ratio of quantity of seepage to the core permeability and bottom width of earth dam (q/K_cB) with sine of downstream slope of core (sin D/S Core), for some models of homogenous earth dam with core at boundary conditions of constant upstream slope earth dam, downstream slope earth dam, permeability of soil for core and earth dam, upstream head and height of dam, with four different upstream slope of core. From this figure, it shown that the discharge increases with increasing sin(D/S Core), the discharge increases with increasing sin(U/S Core). Also, the figure shows that the max. discharge is when both core angles equal to (90°) [sin (U/S Core) & sin (D/S Core) =1]. While the min. discharge at angle (45°) for [sin (U/S Core) & sin (D/S Core) =0.707]. The min. discharge reduces about (25%) from the max value of it. Also, the discharge increases about (5%)when increase in sin(D/s core) from (0.7) to (0.8), about (6.5%) when increase sin(D/S core) from (0.8) to (0.89), and about (22%) when increase in sin(D/s core) from (0.89) to (1).

Figure 5 shows the relationship between the ratio of quantity of seepage to the core permeability and bottom width of earth dam (q/K_cB) with sine of upstream slope of core (sin U/S Core), for some models of homogenous earth dam with core at boundary conditions of constant upstream slope earth dam, downstream slope earth dam, permeability of soil for core and earth dam, upstream head and height of dam, with four different downstream slope of core. From this figure, it can be shown that the discharge increases with increasing sin(U/S Core), and increases with increasing sin(D/S Core). Also, the figure shows that the max. discharge is when both core angles equal to(90°) [sin (U/S Core) & sin (D/S Core) =1]. While the min. discharge at angle (45°) for [sin (U/S Core) & sin (D/S Core) =0.707]. The min. discharge reduces about (31%) from the max value of it. Also, the discharge increases about (6.5%) when increase sin(U/s core) from (0.8) to (0.89) while the discharge increases about (20%) when increase in sin(U/s core) from (0.89) to (1), and about (4.5%) when increase (sin U/S core) from (0.7) to (0.8).

Figure 6 shows the relationship between the ratio of quantity of seepage to the core permeability and bottom width of earth dam (q/K_cB) with sine of downstream slope of dam (sin D/S Dam), for some models of homogenous earth dam with core at boundary conditions of constant upstream slope core, downstream slope core, permeability of soil for core and earth dam, upstream head and height of dam, with three different upstream slope of earth dam. From this figure, it can be shown that the discharge excess with increasing sin(D/S Dam), and increases with increasing sin(U/S Dam). Also, the figure shows that the min. discharge is when upstream dam angle sin(U/S Dam) equal to (0.316) and sin(D/S Dam) equal to (0.371), While the max. discharge is when sin(U/S Dam) equal to (0.406) and sin(D/S Dam) equal to (0.447). Also, the min. discharge reduces about (12%) from the max value of it. The discharge increases about (6.2%) when increase in sin(D/s core) about (9%).

Figure 7 shows the relationship between the ratio of quantity of seepage to the core permeability and bottom width of earth dam (q/K_cB) with sine of upstream slope of dam (sin U/S Dam), for some models of homogenous earth dam with core at boundary conditions of constant upstream slope core, downstream slope core, permeability of soil for core and earth dam, upstream head and height of dam, with three different down stream slope of earth dam. From this figure, it can be shown that the discharge increases with increasing sin(U/S Dam), and increases with increasing sin(D/S Dam). Also, the figure shows that the min. discharge is when downstream dam angle sin(D/S Dam) equal to (0.371) and upstream dam angle sin(U/S Dam) equal to (0.316), while the max. discharge is when upstream dam angle sin(U/S Dam) equal to (0.406) and downstream dam angle sin(D/S Dam) equal to (0.447). The min. discharge reduces about (13%) from the max value of it. Also, the discharge increases about (9%) when increase sin(U/s Dam) from (0.316) to (0.371), while the discharge increases about (5%) when increase in sin(U/s Dam) from (0.371) to (0.406).

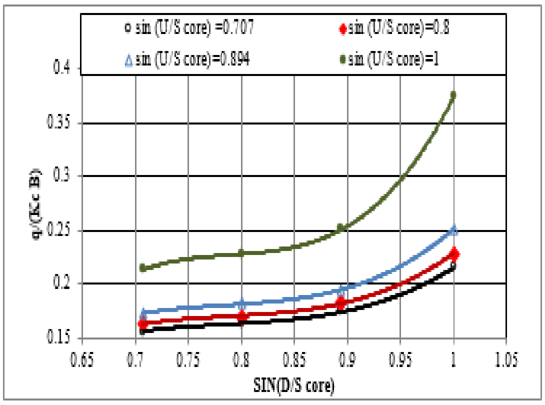

Figure (4): Relationship between (sin(D/S Core) and (q/kcB) of homogenous earth dam with core at U/S Dam 1:3, D/S Dam1:2.5

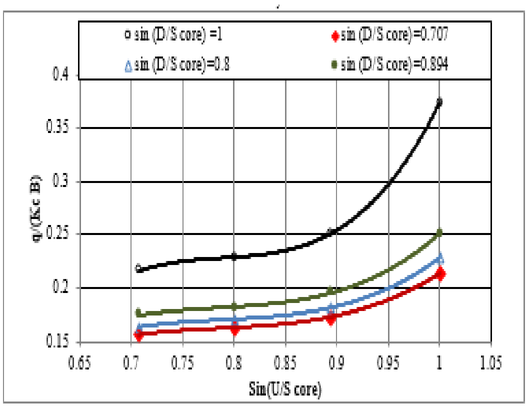

Figure (5): Relationship between (sin(U/S Core)) and (q/kc B) of homogenous earth dam with core at U/S Dam 1:3, D/S Dam1:2.5

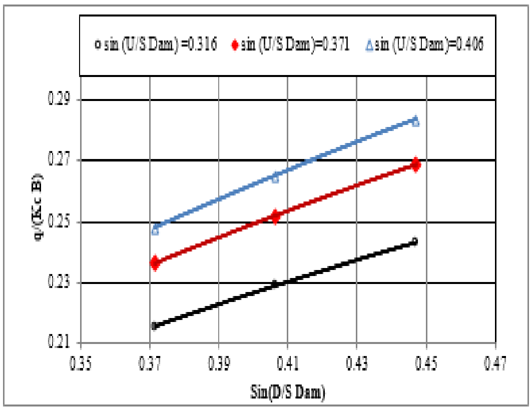

Figure (6): Relationship between (sin(D/S Dam)) and (q/kc B) of homogenous earth dam with core at U/S Core 1:2.5, D/S Core1:2.25

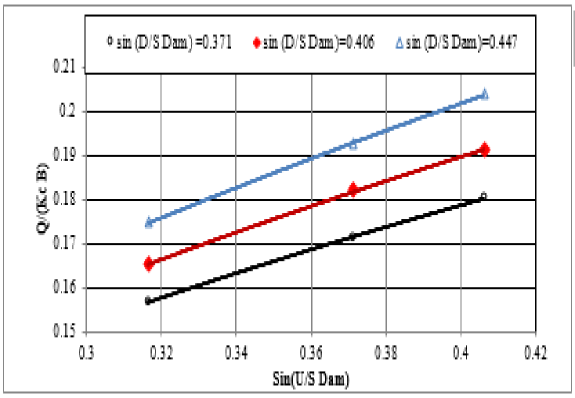

Figure (7) Relationship between (sin(U/S Dam)) and (q/kc B) of homogenous earth dam with core at U/S Core 1:2.5, D/S Core1: 2.5

4.2 Equation For Estimation The quantity of Seepage Through Homogenous Earth Dam With Core

Via substituting about (70%) of the (SEEP/W) model outcome in software program (SPSS) statistics, it will be develop by non-linear regression the subsequent equation 3 which used to estimate the magnitude of seepage running in to homogenous earth dam with core and resting on impervious base:

$$q = \frac{0.642 * k_c * B * \left(\frac{H}{B}\right)^{2.003} * \left(\frac{h}{B}\right)^{1.249} * \left(\frac{b}{B}\right)^{0.351} * \left(\frac{ke}{kc}\right)^{0.632} * \left(\sin\frac{U}{S}Core\right)^{0.13} * \left(\sin\frac{D}{S}Core\right)^{0.172}}{\left(\frac{bc}{B}\right)^{0.387} * \left(\sin\frac{U}{S}Dam\right)^{1.23} * \left(\sin\frac{D}{S}Dam\right)^{0.949}}$$

(3) R^2=0.976

Figure 8 shows the assessment between the residual (30%) of discharge running through the homogenous earth dam with core by (SEEP/W) and those that which calculated from recommended equation 3 using the same features and geometry boundary conditions. Figure 8 shows a good arrangement between the studied discharge from the recommended equation 3 and computing from (SEEP/W) model, also Table 1 show the validation for suggested equation 3.

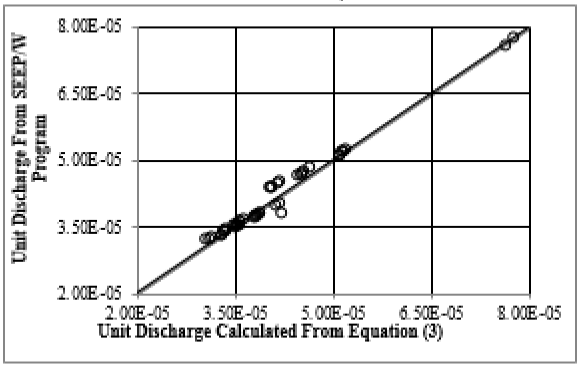

Figure 8: Differentiation between the calculated discharge from the equation 3 and determining from SEEP/W model

Table 1 Statistical Validation of equation (3).

Statistical Standards	Statistical values
Coefficient of Determination (R^2)	97.6%
Mean Absolute Percentage Error (MAPE)	2.63%
Average Accuracy Percentage (AA%)	97.364%

4.4 Artificial Neural Networks (ANN)

Artificial neural networks are stimulated by the learning procedures that take place in biological systems. To recognize what is placed behind this inspiration and biological neurons [24].

ANN are mathematical modeling tools and calculating schemes that are particularly helpful in the field of calculation and estimating in complex sets [23]. These calculating systems are prepared a number of simple and highly intersected processing elements that manner information by their dynamic state response to external inputs [24]. ANN composed of a large number of simple processing units, characterized neurons, which work in an extremely interconnected and parallel method. The consequence is a nonlinear model which is able to study, adapt and create solutions using training data [24].

Multilayer perceptron (MLPs) are the most common and widely used administered algorithms that need input, output pairs. With these pairs the network estimates a function. Apart from supervised algorithms in unsupervised algorithm there is no target to reach and there is no error to back propagate, this kind of algorithms only workings on input pairs and efforts to arrange inputs conferring to pre--specified rules [24].

In this paper the (ANN) model had (3) layers: input layer, hidden layers, and output layer. The input layer had (6) neurons and the output layer had one neuron. But, number of hidden layers and number of neurons in hidden layers can be set. The best number of neurons in the hidden layer was establish by trial and error and it was taken to be in to cases: one hidden layer and two hidden layer, to show the different between them in results as shown in Figure 9. At the dam, four different slopes for upstream, downstream core, and three different slopes for upstream and downstream of dam and different bottom width for core and earth dam were placed in order to observer the flow of water through the dam body.

In Ann used (70%) for training model and (30%) for testing sets, Figure 10 show the relation between the predicted value for (ANN) and the value that calculate using (SEEP/W) which show very good agreement in results when using one hidden layer more than using two hidden layers. In Ann process the normalized important for each independent variable for the case when using one hidden layer had obtained as shown in Table 2.

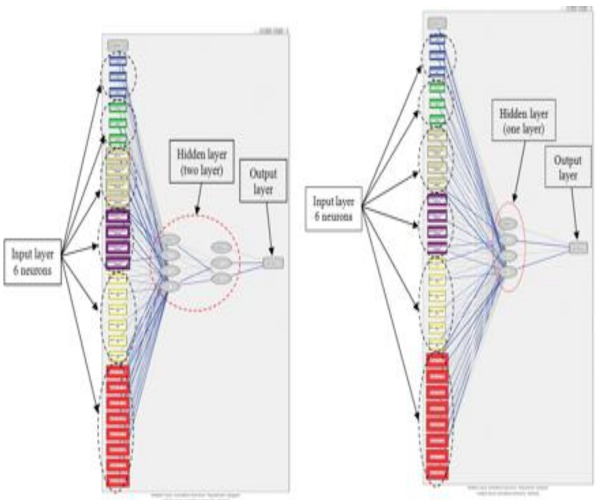

Figure (9): Artificial Neural Network Information for case studied

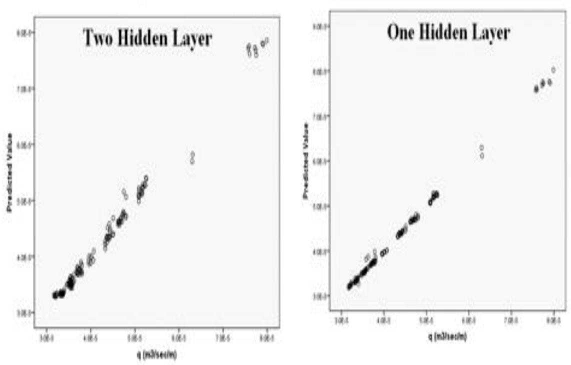

Figure (10): relations between the predicted value for ANN model and the value that calculate using SEEP/W model

Table 2 Independent Variable Importance using one hidden layer

variable	Importance	Normalized Importance
Sin U/S Dam	0.040	10.6%
Sin D/S Dam	0.025	6.7%
Sin U/S Core	0.220	58.7%
Sin D/S Core	0.243	64.6%
B	0.097	25.8%

4.5 Verify Seepage Discharge for Study Cases

Figure 11 match the results from the recommended equation 3, SEEP/W results and the results gained from (ANN) model with one and two hidden layers. Which show good agreement between methods results. Therefore, use the recommended reach equation 3 for estimation the seepage through homogenous earth dam with core resting on impervious base.

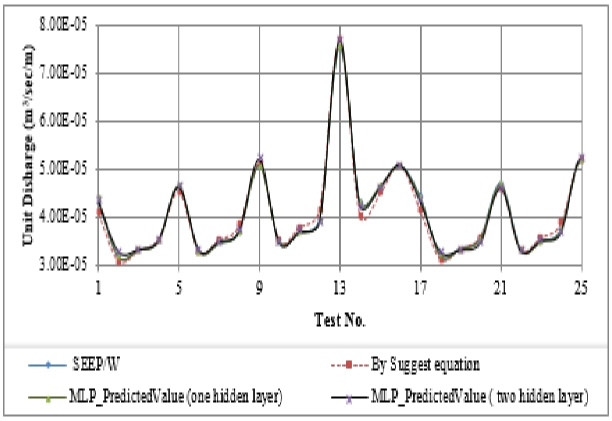

Figure (11): Comparison between the calculated discharge for randomly twenty five tests for different method

5.Conclusions

In the present study, the SEEP/W model and ANN were used to demonstrate the seepage through homogenous earth dam with core which show that:

1. The discharge increases with increasing sin(D/S Core) and sin(U/S Core). Also, the max. discharge is when both core angles equal to (90°) [sin (U/S Core) & sin (D/S Core) =1]. While the min. discharge at angle (45°) for [sin (U/S Core) & sin (D/S Core) =0.707]. The min. discharge reduces about (25%) from the max value of it.

2. The discharge increases with increasing sin(D/S Dam) and sin(U/S Dam). Also, the min. discharge is when upstream dam angle sin(U/S Dam) equal to (0.316) and sin(D/S Dam) equal to (0.371), While the max. discharge is when sin(U/S Dam) equal to (0.406) and sin(D/S Dam) equal to (0.447).
3. Good arrangement between the determined discharge from the recommended equation of paper and computing from SEEP/W model. Also discharge from (ANN) and that calculate using SEEP/W show very good agreement in results when using one hidden layer.
4. The independent variable importance in this paper are: Sin U/S Dam=0.040 (Sin D/S Dam)=0.025, (Sin U/S Core)=0.220, (Sin D/S Core)= 0.243, B=0.097, bc =0.375.

EXAMPLE

An Earth Dam as shown in (Figure 3) which have hydraulic conductivity: (1×10^{-3} and 1×10^{-6}) m/sec for dam and core respectively, slopes of core were (1:0.8, 1:0.85) for upstream and downstream core respectively, slopes of dam were (1:3, 1:2.5) for upstream and downstream dam respectively, The height of dam (35m), the upstream head is (30m), top width for dam (10m) What will be the amount of seepage through earth dam.

Given: $K_e= 1\times10^{-3}$m/sec, $K_c=1\times10^{-6}$m/sec, U/S core 1:0.8, D/S core= 1:0.85, U/S dam= 1:3, D/S dam =1:2.5, H=35m. h=30m, b=10m.

Solution: by using equation 8, $q = 3.5\times 10^{-5}\, \frac{m^3}{sec}\big/ m$ *(Ans.)*

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