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Determination of discharge coefficient of inbuilt spillway in rock- fill dams

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ABSTRACT

According to the former researcher's presented relations for flow through rock-fill porous media, the effects of physical characteristics was not studied separately. Hence, due to the application of these relations, physical characteristics of porous materials effect must be investigated separately. In various constructed physical models of porous media, the effect of several variables such as unified coefficient of materials, kind of materials, material gradation and material figures on the parameters such as void ratio, raggedness and specified surface area of materials have been studied. These parameters have a significant effect on the flow discharge coefficient through rock-fill porous materials. In the defined research during this paper, using artificial unique spherical materials with diameters of 10, 37 and 75 mm with the same configuration, the effect of parameters including specified area of rock-fill materials, figure of rock-fill materials and the size of rock-fill materials on the hydraulic characteristics of discharge flow through rock-fill porous media in rock-fill dam models with inbuilt spillway and spillways on the upstream face, have been studied. Also, using the data of these experiments in combination with the data of experiments of the former researches on the natural rock-fill materials, dimensionless relations of Bazargan have been investigated. Finally, using statistical multi variable analysis, a dimensionless relation with maximum correlation coefficient and acceptable accuracy based on the physical characteristics has been presented.

Keywords

Porousmedia; Discharge coefficient; Inbuilt spillways

1. Introduction

Studying of flow behavior through rock-fill coarse porous materials, we have to define appropriate relations between hydraulic gradient and flow velocity. In this regard, a relation could be appropriate and applicable which needs lesser parameters for designing and at the same time, have an acceptable accuracy. Whereas, within the larger void diameter, such as rock drain in earth-fill dams and rock-fill dams the flow may be transitional or turbulent. In such a case Darcy's law does not apply properly because the relation between hydraulic gradient and velocity is not linear (Bazargan and Byatt,

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2002). Generally, flow triplet classified regions through porous media are as follows:

1. Laminar flow: When flow is Laminar, Reynolds number is proportional to the ratio of inertia force to the frictional force, and inertia force value is negligible in comparison to the frictional force.
2. Transitional flow: By increasing Reynolds number, inertia force and frictional force values are significant and the relation between hydraulic gradient and flow velocity is non-linear.
3. Turbulent flow: In perfect turbulent flow, fluid viscosity force is negligible in comparison to viscosity force.

Triplet zones of flow through a self-spillway rock-fill dam have been shown in the Fig1.

Based on the Parkin's main research for flow through rock-fill dams having inbuilt spillways, four zones are predictable. These four zones are shown schematically. Figure 1 and these zones are described as follows (Stephenson 1969):

1. Zone between upstream level and inbuilt spillway's crest: Almost, in this zone flow path is horizontal and flow is laminar.
2. Zone on the inbuilt spillway's crest: in this zone flow behavior is a rapid varied one.
3. Zone after inbuilt spillway: In this zone, flow has a free downfall behavior; and in low discharge, flow is mixed with the air.
4. Zone between inbuilt spillway and tail water: In this zone, flow behavior is comparable with gradually varied flow in open channel and profile of flow is estimated with gradually varied flow governed equations.

When flow through porous media is laminar - as in fine materials such as clay and silt a linear relation is governed between hydraulic gradient and velocity; this relation is presented as follows (Venkatarmand Rao 1998):

$$i = \left[\frac{1}{K}\right] v \qquad (1)$$

Where V= bulk velocity; K= hydraulic conductivity and i= hydraulic gradient.

Due to the analysis of laminar, transitional and turbulent flows in rockfill materials or porous media,various equations have been presented, which can be presented by power-type equations such as Missbach equation or Forchheimer binomial equation. Power-type equations have the accuracy and applicability just for a limited Reynolds Number variation. Therefore, absolutely this is not proposed due to the analysis of laminar, transitional and turbulent flows. But, Forchheimer equation that is demonstrable by dimensional analysis and navier stokes equations has an appropriate accuracy for all three types of flow. Furthermore, several researchers have presented their equations using various definitions of the Reynolds number, and Darcy Weisbach friction coefficients in various forms. These models are divided to two types; the first type of these models has acceptable accuracy; but for determining the needed parameters for usability of these models, we have to determine the permeability of the materials. For obtaining permeability coefficient, we need to have a couple of experimental data of hydraulic gradient and velocity. In the second model, we do not need the permeability coefficient, in spite of application of these models, accuracy of these models are not acceptable. In this paper, an experimental investigation is carried out by obtaining accurate permeability coefficients of materials for calculating Rm = (modified Reynolds number), (Bazargan2002) and frictional coefficient.

Forchheimer binomial based model is

presented as follows:

$$i = aV + bV^2 \tag{2}$$

This model is used by other researchers (Muskat 1949, Schieidgger 1963, Linquist1965 cited by Bazargan 2002, Ward 1964, Ahmed andSunada 1969) and its applicability was confirmed for flow through porous media.

Various researchers have tried to relate a and b coefficients to the physical properties of the porous media. Their results have been presented in several forms (Leps 1973, Bazargan 2002).

Ward (1964), Ahmed and Sunada (1969), using dimensional analysis for one dimensional macroscopic flow, showed that parameters a and b in equation (2) may be written in this form:

$$a = \frac{\mu}{\rho g k} \tag{3}$$

$$b = \frac{1}{g\sqrt{ck}} \tag{4}$$

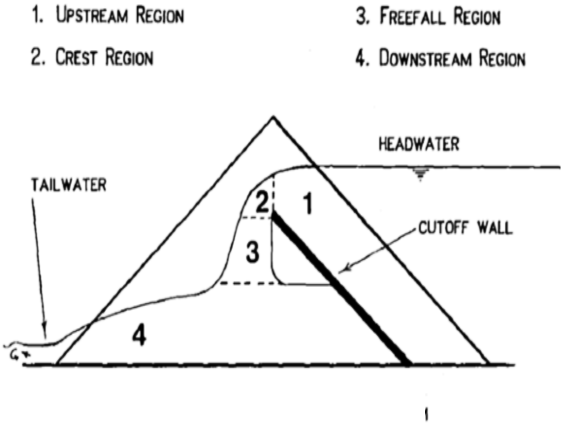

Fig. 1. Zones of flow within a self-spillway flow through rock-fill dam (after Parkin1963)(Mahbubi, J. &Bayat H. A, 2008)

Where μ = dynamic viscosity, ρ = fluid density, g = gravitational acceleration, k = intrinsic permeability and c = experimental dimensionless coefficient. And then can be written as follows:

$$i = aV + bV^2 = \frac{\mu}{\rho g k}V + \frac{1}{g\sqrt{ck}}V^2$$

$$i = \left\{\frac{\mu}{\rho g k} + \frac{1}{g\sqrt{ck}}V\right\}\cdot V = \frac{\mu}{\rho g}\left\{\frac{1}{k} + \frac{\rho}{\mu\sqrt{ck}}V\right\}\cdot V \tag{5}$$

If actual velocity is used instead of the bulk velocity in the above equations and by definition of J with this form:

$$j = \frac{1}{\frac{1}{k} + \frac{\rho V_a}{\mu\sqrt{c'k'}}} \tag{6}$$

where c', k' are the same parameters as c, k by using the actual velocity it can be written:

$$i_t = i = \frac{\mu}{\rho g j}V_a \tag{7}$$

Where in Laminar flow j≈k, now, if the parameter of R_m or the same new dimensionless number is defined in the form of the ratio of inertia force to frictional force and defined as follows:

$$R_m = \frac{\rho\sqrt{j}}{\mu}V_a \tag{8}$$

$$f = \frac{1}{R_e} + c_w \tag{9}$$

$$R_e = \frac{V\rho\sqrt{k}}{\mu} \tag{10}$$

Where f = Darcy-Weisbach coefficient and c_w = Ward's coefficient (the estimated the mean value of this coefficient equal to 0.55) and Ward's proposed Reynolds number is described in equation (10).

Ahmed and Sunada (1969) used Navier-Stokes equation for one dimensional macroscopic flows and derived equations (11) and (12) for obtaining parameters of a and b in Forchheimer equation (Ahmed and Sunada 1969, Bazargan 2002). In the above-mentioned equation laminar Weisbach coefficient and Reynolds number is defined as follows:

$$f = \frac{1}{R_e} + 1 \qquad (11)$$

$$R_e = \frac{\rho V d}{\mu} \qquad (12)$$

$$k = cd^2 \qquad (13)$$

Where, c = material's dimensionless coefficient and d = parameter of characterized length that shows the effective diameter of the pore. Equation (13) is applicable in equations (5) to (12).

In Laminar flow: $R_m \le 0.02027\sqrt{c}$

In transient flow: $0.02027\sqrt{c} < R_m < 9.9\sqrt{c}$

In perfect turbulent flow: $R_m > 9.9\sqrt{c}$

$$R_{m_C} = 0.02027\sqrt{c} \qquad (14)$$

$$R_{mt} = 9.9\sqrt{c} \qquad (15)$$

According to the equations (14) and (15), boundaries of Laminar, transient and turbulent flow have been specified.

2. Experimental Methods and Models

Physical characteristics of porous materials effect on the presented relations must be specified due to the developmental application of a new parametric relation to the prototype case study. For more investigations the effect of physical characteristics such as volume-specific surface area, size of materials, void ratio, gradation, unified coefficient and number of R_m on hydraulic parameters of flow such as discharge coefficient (C_d) through rock-fill materials like rock-fill dams, six Dam models have been constructed with spherically same size materials in three diameter sizes of 10, 37 and 75 mm. Dam model with 37 mm has been shown in Figure 3. For every size, two dam models have been constructed with inbuilt spillways and spillways on the upstream face of the dam. Models have been constructed in the flume with length=4.2 m, width=30 cm, height=30 cm. For the simplification of calculation in this paper, volume-specified surface area is used.

In this experimental research, the researchers have used the same arrangement that leads to the same minimum void ratio for three same diameter size spherical materials. Details of these models have been shown according to the Fig 2 , 3 and Table1.

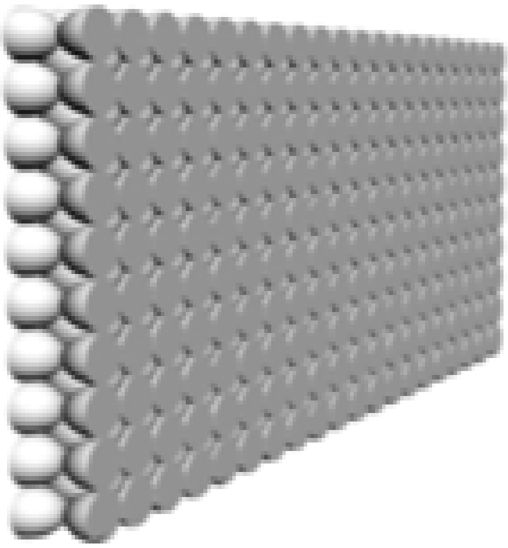

Fig. 2. Minimum repetitive section in porous medium with spherical particles with minimum void ratio.

Table1. Characteristics of Spherical Particles

Model Number	1	2	3
Particle size = d(m)	0.01	0.037	0.075
Surface of one spherical particle (m^2)	0.000314	0.004299	0.017663
Volume of one	5.23333E-07	2.65084E-05	0.0002
specific surface area (m-1)	600	162.1622	80
Porosity (n)	0.359	0.359	0.359
void ratio (e)	0.559	0.559	0.559

Fig. 3. Dam model with the same size diameter materials (Diameter = 37 mm) with inbuilt spillway on the upstream face

Porosity and void ratio are independent from thediameter of particles and just depend on setup of particles. Determination of volume-specified surface area in the experimented models:

Ams (mass-specific surface area) = surface area of one particle/ one particle mas (16)

Avs (volume-specific surface area) = the surface area of one particle /volume of one particl (17)

2.1. Obtaining Cd Based on the Dimensionless Parameters

For calculation of discharge coefficient through dam's inbuilt spillway of rock-fill dams, we can simulate inbuilt spillway with the rectangular sharp crested weir; and hence, C_d to be calculated as follows (Mahbubi, J. &Bayat H. A 2008):

$$q=\frac{2}{3}\sqrt{2g}C_d H_d^{3/2} \tag{18}$$

And then:

$$C_d=\frac{q}{\frac{2}{3}\sqrt{2g}H_d^{3/2}} \tag{19}$$

Discharge value based on the dimensionless parameters can be calculated as follows

$$\frac{q}{\sqrt{g}\,p^{1.5}}=F(C_u.C_c,e,\frac{h_e}{p},i,D,A_{vs},R_m) \tag{20}$$

Where, p= height of inbuilt spillway, n=media's porosity, C_u =unification coefficient, C_c =grading coefficient, e=void ratio and h_e= height of flow on the inbuilt spillway. If we suppose:

$$\alpha=F(C_u.C_c,e,\frac{h_e}{p},i,D,A_{vs},R_m)$$

therefore, dimensionless coefficient (α) can be calculated as follows:

$$\alpha=q\sqrt{g}\,p^{1.5} \tag{21}$$

and by substituting equation (7) in the equation (5), C_d can be calculated as follows:

$$C_d=\frac{3\alpha P^{1.5}}{2\sqrt{2}H_d^{3/2}} \tag{22}$$

Finally, the parameter C_d, based on the parameters included (C_u), (C_c), (d_{50}), (h_e) and (i) can be calculated.

Experimental Findings

Hydraulic gradient can be calculated as follows:

$$i=\frac{H_{us}-H_{ds}}{L} \tag{23}$$

Where, H_{us} and H_{ds} can be calculated as follows:

$$H_{us}=Z_{us}+\frac{V^2{}_{us}}{2g}+\frac{P_{us}}{\gamma} \tag{24}$$

$$H_{ds}=Z_{ds}+\frac{V^2{}_{ds}}{2g}+\frac{P_{ds}}{\gamma} \tag{25}$$

Flow velocity in dam's upstream can be calculated as follows:

$$V_{us}=\frac{q}{h_e n} \tag{26}$$

Flow velocity in dam's downstream can be calculated as follows:

$$V_{ds} = \frac{q}{h_{ds} n} \quad (27)$$

Where, n is porosity and can be calculated as follows:

$$n = \frac{e}{1+e} \quad (28)$$

Average flow velocity through rock-fill dam can be calculated as follows:

$$V_{av} = \frac{V_i + V_{i-1} + V_{i-2} + ... + V_1}{i} \quad (29)$$

2.2. Data of experiments based on the above relations have been calculated and then presented as follows

According to the above table, values a and b are 2.227 and 2.601 respectively. Significant values of a and b are 0.000 and 0.021 respectively that are significant for the value of a and b on fitted Forchheimer equation between values I and V. With regard to value zero for P value of coefficient a that is less than 0.05, it can be said this coefficient is acceptable with minimum assurance of 95%.

Where.

$$F_r^2 = \frac{V_a^2}{g\sqrt{j}},$$

$$j_c = \frac{k}{1.02048} \qquad j_t = \frac{k}{100}$$

$$Vc = 0.020408 \times \frac{\mu}{\rho}\sqrt{\frac{c}{k}} \text{ and, } V_t = 99 \times \frac{\mu}{\rho}\sqrt{\frac{c}{k}}$$

2.3. Hydraulic characteristics of flow through dam's model constructed by rock-fill materials

According to the above table, values a and b are 7.599 and 0.424 respectively. Significant values of a and b are 0.000 and 0.965 respectively that show perfect significant for value of a, and also, insignificancy for coefficient bon fitted Forchheimer equation between values I and V(Fig 4, 5 and table 2, 5).with regard to value zero for P value of coefficient a that is less than 0.05, can be said this coefficient is acceptable with minimum assurance of 95%.

According to the Fig 6, can be shown by increasing the diameter of materials or effective length of pores, the parameter of R_{mc} increases. According to the Fig 6, and also, based on the correlation coefficient and fitted curve, can be observed that linear relation is a appropriate fit for showing variation between R_{mc} and diameters of materials.

$$R_{mc}=A(D)+B \quad (30)$$

When void rate value and flow discharge value is constant for the same setup of spherical materials, by increasing diameters of materials and effective flow height, discharge coefficient decreases.

Diagram shows by increasing diameters of materials (D), discharge coefficient decreases, and also, according to the diagram power type relation has an appropriate fit for showing variation of Cd versus D.

$$C_d = A.(D)^B \quad (31)$$

Hydraulic parameters of dam's model constructed by same size spherical materials with diameter 37 mm also by rock-fill materials and spillway on the upstream facehave been shown according to the Table3, 6 and in Tables 4-a-b, 7-a-b hydraulic parameters have been Calculated.

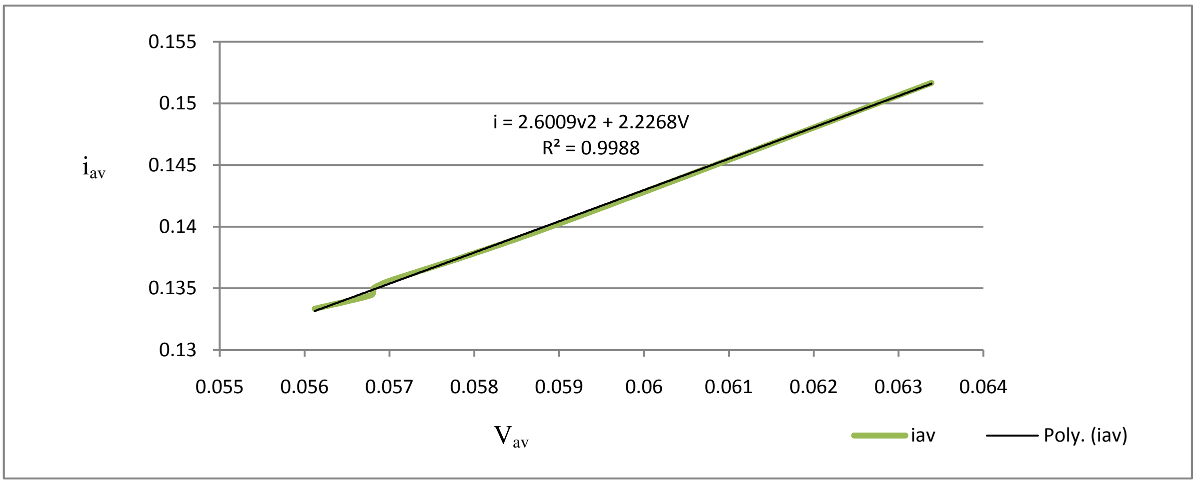

Fig. 4. Diagram of fitted curve on Forchheimer equation between values I and V(m/s)

Table 2. Coefficients values of a and b in fitted Forchheimer equation between values I and V

	Unstandardized Coefficients		Standardized Coefficients	t	Sig.
	B	Std.Error	Beta	B	Std. Error
Vav(a)	2.227	.041	.936	53.714	.000
Vav ** 2(b)	2.601	.709	.064	3.667	.021

Table 3. Hydraulic parameters of dam's model constructed by same size spherical materials with diameter 37 mm and spillway on the upstream face

Hus	Hds	a	Cd	he	yc	L	Vav	q(lit/s)	P	Hd
18.9	5.350	0.014	0.070	5.8	19.1	111.0	0.062	2.230	14.0	4.9
18.8	5.300	0.012	0.064	5.1	19.1	111.5	0.057	1.998	14.0	4.8
18.7	5.100	0.012	0.064	4.9	19.0	112.0	0.055	1.911	14.0	4.7
18.7	5.050	0.011	0.062	3.5	17.5	113.0	0.055	1.845	14.0	4.7
18.6	4.900	0.011	0.063	3.4	17.4	114.0	0.055	1.825	14.0	4.6
18.0	4.650	0.010	0.071	3.3	17.1	115.0	0.054	1.672	14.0	4.0
18.7	5.050	0.011	0.062	3.5	17.5	113.0	0.055	1.845	14.0	4.7
18.6	4.900	0.011	0.063	3.4	17.4	114.0	0.055	1.825	14.0	4.6
18.4	4.800	0.011	0.065	3.4	17.3	114.3	0.056	1.784	14.0	4.4
18.2	4.700	0.010	0.067	3.3	17.2	114.5	0.055	1.708	14.0	4.2
18.0	4.650	0.010	0.071	3.3	17.1	115.0	0.054	1.672	14.0	4.0

Table 4-a. Calculated hydraulic parameters based on the data of Table 3

a	b	k	c	d	
2.22680	2.60090	0.0000000368965	41632.24725	0.0000009	
V_{av}(m/s)	J	Rm	f=1/Rm	Fr^2	i_t
0.062	3E-08	14.1918572	0.07046	2.0785	0.146
0.057	3E-08	13.2191023	0.07565	1.7905	0.135
0.055	3E-08	12.8006152	0.07812	1.6737	0.131
0.055	3E-08	12.7640192	0.07835	1.6637	0.13
0.055	3E-08	12.7579566	0.07838	1.6621	0.13

Table 4-b. Calculated hydraulic parameters based on the data of Table3

Rmc	Rmt	Vc(m/s)	Vt(m/s)	jc	jt	Cw
0.062	3E-08	14.19	0.07	2.078	0.146	4.136
0.057	3E-08	13.22	0.076	1.79	0.135	4.136
0.055	3E-08	12.8	0.078	1.674	0.131	4.136
0.055	3E-08	12.76	0.078	1.664	0.13	4.136
0.055	3E-08	12.76	0.078	1.662	0.13	4.136
0.054	3E-08	12.61	0.079	1.623	0.129	4.136

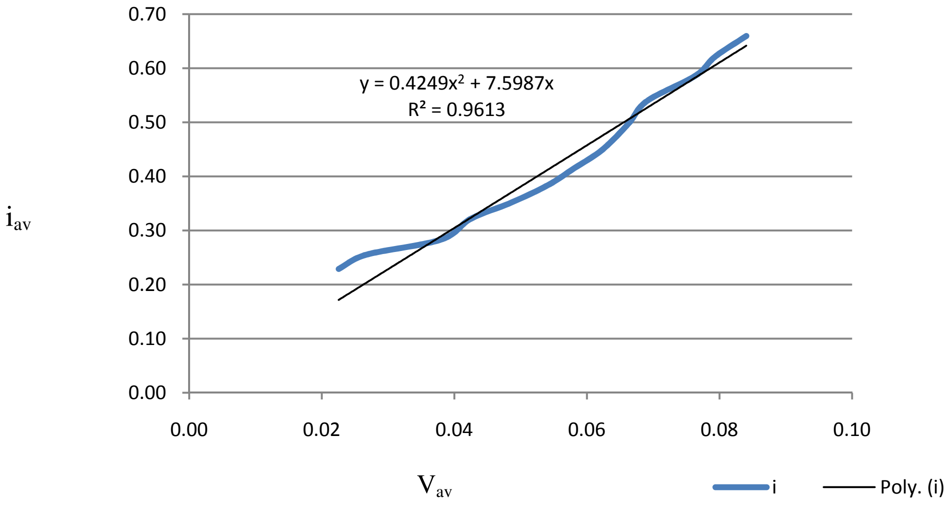

Fig. 5. diagram of fitted curve on Forchheimer equation between values I and V(m/s)

Table 5. Coefficients values of a and b in fitted Forchheimer equation between values I and V

	Unstandardized Coefficients		Standardized Coefficients	t	Sig.
	B	Std. Error	Beta	B	Std. Error
Vav(a)	7.599	.645	.995	11.790	.000
Vav ** 2(b)	.424	9.422	.004	.045	.965

Table 6. Hydraulic parameters of dam's model constructed by rock-fill materials with spillway on the upstream dace - Cu=1.54, e=0.85

Hus	Hds	he	hq	L	q(lit/s)	a	Cd
21.0	4.3	0.4	1.7	73.0	0.1	0.000	0.026
22.0	4.4	1.2	2.6	69.0	0.2	0.001	0.028
23.0	4.6	2.1	3.5	65.0	0.5	0.002	0.034
24.0	4.7	3.0	4.0	60.0	0.7	0.003	0.031
25.0	4.8	4.0	4.5	57.5	1.0	0.004	0.030
26.0	4.9	4.9	4.9	55.0	1.2	0.004	0.029
27.0	5.0	5.7	5.2	53.0	1.5	0.005	0.027
28.0	5.1	6.6	5.5	51.0	1.7	0.006	0.025
29.0	5.1	7.1	5.7	48.0	1.9	0.007	0.023
30.0	5.2	7.8	5.9	46.0	2.0	0.007	0.022
31.0	5.2	8.4	6.2	44.0	2.3	0.008	0.021
32.0	5.3	9.2	6.4	43.0	2.5	0.009	0.020
33.0	5.3	9.8	6.6	42.0	2.7	0.010	0.020

Table 7-a. Hydraulic characteristics of flow through dam's model constructed by natural rock-fill materials

a	b	k	c	d	
7.59870	0.42490	0.000000011	5323065.220243580	0.000000045	
Vav(m/s)	J	Rm	f=1/Rm	Fr^2	i_t
0.02255	1.08E-08	2.91460394	0.34309979	0.49880987	0.171142
0.0267	1.08E-08	3.45059364	0.289805206	0.69938274	0.202685
0.038	1.08E-08	4.9094049	0.203690675	1.4170882	0.288648
0.0425	1.08E-08	5.49009086	0.182146348	1.77281004	0.322911
0.04855	1.08E-08	6.27056075	0.159475371	2.31385568	0.369003
0.0541	1.08E-08	6.98629704	0.143137344	2.87355618	0.411313
0.0581	1.08E-08	7.50200548	0.13329769	3.3145606	0.441823
0.0623	1.08E-08	8.0433754	0.124325914	3.81154231	0.473873
0.0663	1.08E-08	8.55884783	0.116838156	4.31718067	0.504411
0.06905	1.08E-08	8.91316839	0.11219355	4.68310485	0.525414
0.0764	1.08E-08	9.85990391	0.101420867	5.73432545	0.58158
0.0793	1.08E-08	10.2333391	0.097719815	6.17841593	0.603754
0.08405	1.08E-08	10.8448697	0.092209499	6.94166672	0.640088

Table 7-b. Hydraulic characteristics of flow through dam's model constructed by natural rock-fill materials

Rmc	Rmt	Vc(m/s)	Vt(m/s)	jc	jt	Cw
0.02255	1.08E-08	2.91460394	0.34309979	0.49880987	0.171142	46.76648
0.0267	1.08E-08	3.45059364	0.289805206	0.69938274	0.202685	46.76648
0.038	1.08E-08	4.9094049	0.203690675	1.4170882	0.288648	46.76648
0.0425	1.08E-08	5.49009086	0.182146348	1.77281004	0.322911	46.76648
0.04855	1.08E-08	6.27056075	0.159475371	2.31385568	0.369003	46.76648
0.0541	1.08E-08	6.98629704	0.143137344	2.87355618	0.411313	46.76648
0.0581	1.08E-08	7.50200548	0.13329769	3.3145606	0.441823	46.76648
0.0623	1.08E-08	8.0433754	0.124325914	3.81154231	0.473873	46.76648
0.0663	1.08E-08	8.55884783	0.116838156	4.31718067	0.504411	46.76648
0.06905	1.08E-08	8.91316839	0.11219355	4.68310485	0.525414	46.76648
0.0764	1.08E-08	9.85990391	0.101420867	5.73432545	0.58158	46.76648
0.0793	1.08E-08	10.2333391	0.097719815	6.17841593	0.603754	46.76648

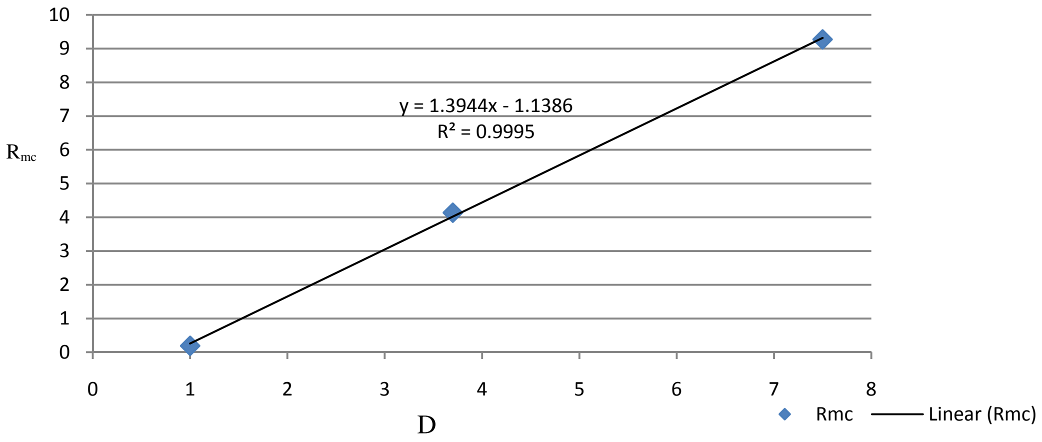

Fig.6. Diagram of variation of Rmc versus variation of materials diameters has been shown in the above diagramD(mm)

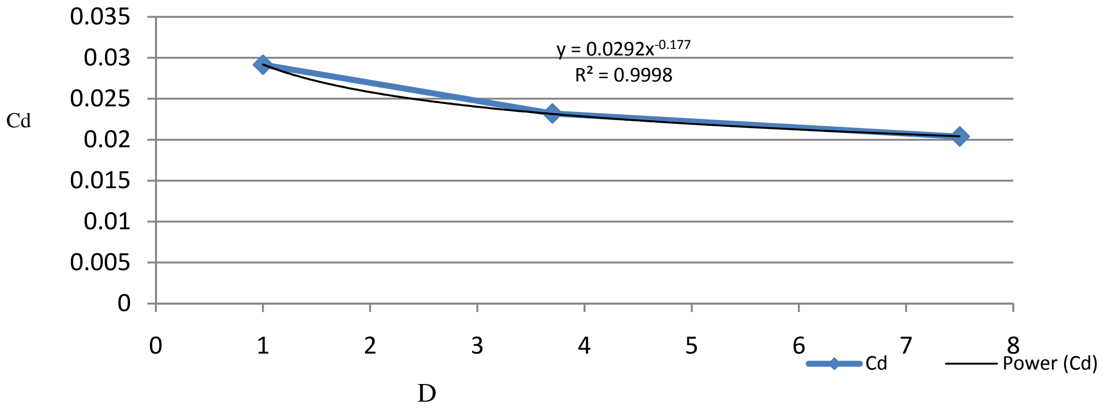

Fig.7. Diagram of variation of C_d versus variation of materials diameters has been shown in the above diagram.D(mm)

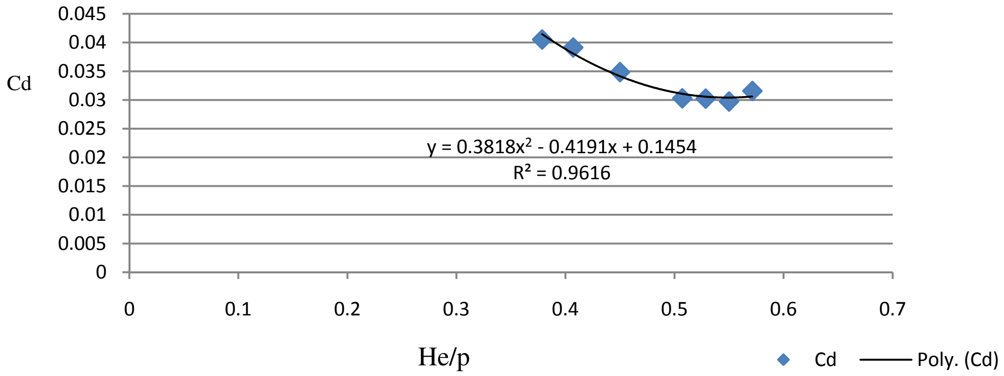

Fig. 8. Diagram of discharge coefficient variation versus variation of dimensionless energy

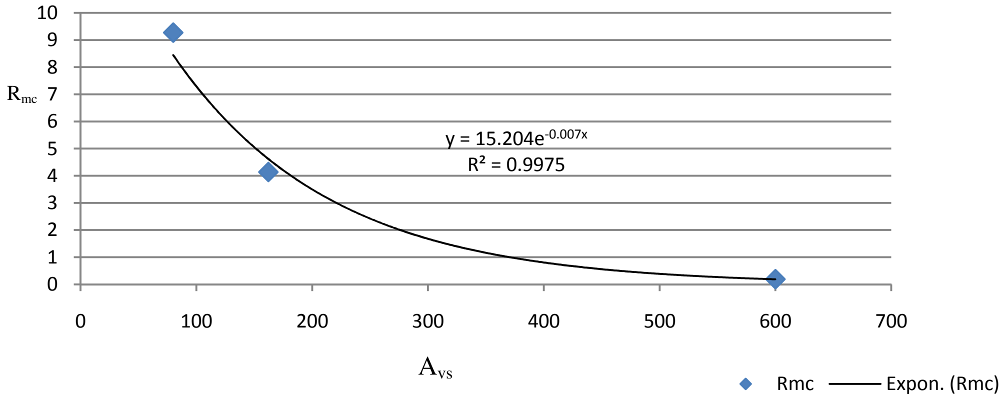

Fig. 9. Variation of R_{mc} versus volume-specific area surface of spherical materials

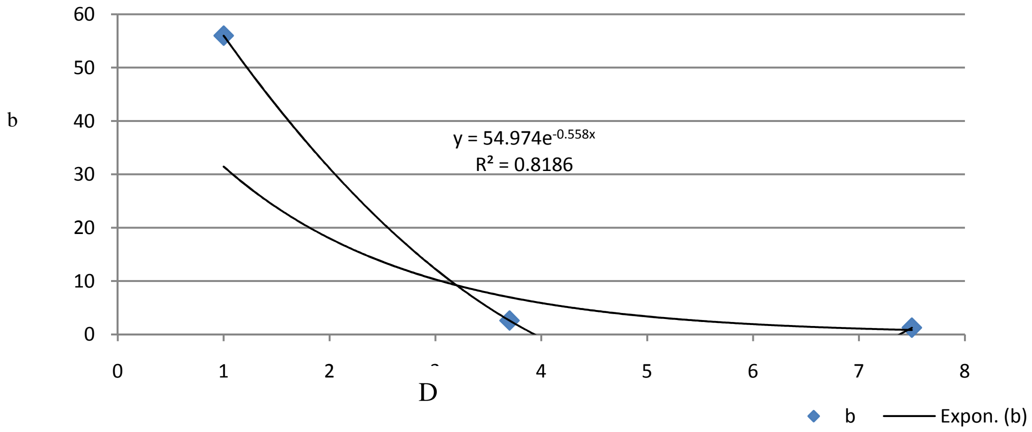

Fig. 10. Diagram of variation of coefficient of b in equation of Forchheimer versus unique size materials diameters in constructed dams models with spillway on the upstream face.D(mm)

Table8. Nonlinear regression coefficient

Parameter Estimate

parameter	Estimate	Std.Error	95% Confidence Interval	
			Lower Bound	Upper Bound
a	.010	.000	.006	.015
b	-2.103	.043	-2.647	-1.558
c	6.09E-024	.000	-130E-021	1.31E-021
f	-33.080	10.381	-164.983	98.823
I	3.407	.101	2.124	4.690
n	-.103	.012	-.250	.043
k	.012	.003	-.027	.051

Table 9. Linear regression coefficient

Source	Sum of Squares	df	Mean Squares
Regression	0.010	7	0.001
Residual	0.0001823	1	0.018
Uncorrected Total	0.01	8	
Corrected Total	0.002	7	

Whereas, flow discharge varies by power of 1.5 for effective height, and also by increasing effective, flow discharge increases and therefore, discharge coefficient decreases. According to the diagram in the figure 7 that shown variation of Cd versus variation of materials diametersD(m/s).also in figure 8 and also based on the correlation coefficient and fitted curve, it can be observed that polynomial relation is an appropriate fit for showing variation between R_{mc} and diameters of materials.

$$C_d = A\left(\frac{He}{P}\right)^2 + B(he/p) + C \qquad (32)$$

According to the Fig. 9 and also based on the correlation coefficient and fitted curve, it can be observed that exponential relation is an appropriate fit for showing variation between R_{mc} and diameters of materials (Haghighi M. &Bayat H. A,2003).

$$R_{mc=}Ae^{B(A_{vs})} \qquad (33)$$

According to the diagram figure 9, by increasing volume specific surface area, R_{mc} decreases because by increasing A_{vs} that equals decreasing in materials diameters, flow reaches the critical state with lower number of R_{mc}.

To apply the results of this experimental investigation, based on the multivariate analyses with SPSS and engineering judgment the following relation has been achieved. The correlation coefficient between experimental data for the investigated parameters and presented relation has an acceptable accuracy and has perfect degree of fitting coefficient between parameters (table 8,9).

$$C_d = (ai^b + c(\frac{he}{P})^f) \times e^l \times R_m{}^n \times C_w{}^k \qquad (34)$$

In the above relation coefficients and powers of n, I, f, c, b, a and k are unknown and obtained from multivariate analyses by SPSS as follows:

NEW FILE.
DATA SET NAME Data Set 2 WINDOW= FRONT.

* NonLinear Regression.

MODEL PROGRAM:
a=0.01 b=0.01 c=0.01 f=0.01 l=0.01 n=0.01 k=0.01.

$$COMPUTE\ PRED = \left(ai^{b} + c(\frac{h_e}{p})^{f} \right) e^{l} R_m^{n} C_w^{k}$$

Dependent Variable: C_d

$$R\ squared = 1 - \frac{(Residual\ Sum\ of\ squares)}{(Corrected\ Sum\ of\ Squares)} \qquad (35)$$

$$R\ squared = 0.90885$$

According to the obtained coefficients, flow discharge coefficient based on the rock-fill characteristics presented as follows:

$$C_d = \left(0.01 i^{2.103} + 6.0 \times 10^{-24} (\frac{he}{P})^{-33.08} \right) e^{3.407} R_m^{-0.103} C_w^{0.012} \qquad (36)$$

According to the analysis by SPSS, the regression coefficient for fitted relation between recorded data is 0.90885 that has an acceptable accuracy.

4. Conclusions

By increasing volume-specific surface area of spherical materials, values (R_{mt}) and (R_{mc}) decrease because, increasing volume-specific surface area is equal to decreasing in diameter; hence, flow reach the critical state and turbulent state with lesser values of (R_{mt}) and (R_{mc}).

By increasing flow height over crest of inbuilt spillway, discharge coefficient decreases; because, discharge value through dam's body is proportionate with power 1.5 of flow height over crest of inbuilt spillway; therefore, discharge coefficient decreases.

By increasing diameters of materials, coefficient of b in Forchheimer equation decreases (figure 10). Whereas, configuration of materials in all models are the same; hence, void ratio will be the same in all models; therefore, it could not be concluded that by increasing diameters of materials in models, coefficient of b will increase. By increasing diameters of materials, situation of pores are not perfectly in the length of flow path; therefore, by increasing diameters of material in the same configuration models, contribution rate of pores in discharge flow decrease; and finally, flow trend to the laminar state and coefficient of b decreases.

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