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Geometric optimization of stepped spillways using genetic algorithm

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Abstract

Recent advances in technology have created wide possibilities for building large dams, reservoirs and canals. These advances require the development of design and construction methods, especially for systems that can discharge sufficient flood. Shots and overflows are designed in such a way that no major damage is caused to the structure itself or to the surrounding environment to pass large flows through a hydraulic structure. During the flow of water over the spillway, it is necessary to consume some energy in order to prevent damage to the toe of the dam and its surroundings and finally to the dam itself. In this research, a method was presented to optimize the geometric parameters of the stepped overflow. For this purpose, using laboratory model data (275 tests in total). And the use of strong statistical software WEKA and MATLAB software obtained a formula to predict the amount of energy consumption. This formula was given to the genetic algorithm as an objective function. Entering the Yc/Hdam parameter, which includes both the flow rate and the total height of the dam, and the desired energy consumption value, this program is optimized by genetic algorithm and obtains the optimal number, length and width of steps. The results of this research show that: with the increase in flow rate, the amount of maximum energy consumption decreases, and with the increase of the head slope at a constant flow rate, the number of optimal steps for equal energy consumption increases. © 2017 Journals-Researchers. All rights reserved. (DOI:https//**doi.org/10.52547/JCER.5.1.31**)

Keywords: Genetic algorithm, optimization of geometric, energy dissipation, stepped spillways

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1. *Introduction*

Recent advances in technology have created wide possibilities for the construction of large dams, reservoirs and canals. These advances require the development of: design and construction methods, especially for systems that can discharge sufficient flood. Shots and overflows are designed in such a way that no major damage is caused to the structure itself or to the surrounding environment to pass large flows through a hydraulic structure. With free fall, it flows at a considerable speed, and it is necessary that some of its energy be consumed in order to prevent damage to the dam's toe and its surroundings, and finally the dam itself. The energy resulting from the overflow flow is usually consumed by the following methods:

1. By reducing the speed of the water flow through the throwing cup (or from the crown of the dam) and throwing it into a pool full of water at the bottom, which acts like a water cushion.

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2. Construction of a standard relaxation pond downstream of the overflow in such a way that the hydraulic jump created in it can consume a significant amount of energy.

3. Installing a number of steps on the overflow to help energy consumption.

In the first two methods, a major part of the energy at the lower end of the hand is consumed in the middle of the pool filled with water and in the relaxation pool, respectively. The stairs in the stair overflow can significantly increase the intensity of energy consumption resulting from the shot and need. To build a system to eliminate energy consumption in the downstream or reduce it to a considerable extent.

The flow of water on an uneven or stepped floor is very turbulent and this type of flow can consume a large part of its energy.

During the last three decades, a large number of earthen dams have been designed using a concrete body and in the form of a step. In recent years, the tendency towards stair overflows is growing and the main reason is that they are economical. Compared to smooth weirs, the discharge of flood unit will be smaller and limited to At the same time, the possibility of cavitation is also less. In general, the stepped shot of an overflow can consume more energy than the smooth shot, and as a result, the amount of remaining energy at the end that must be consumed by the depleting structures will be much less than normal.

A stair overflow consists of steps that start from near the crown of the overflow and continue to the bottom heel. The use of stair overflows has been common since ancient times (3500 years or more) and their design method was abandoned in the 1920s. But in recent years, attention to this type of overflows has increased due to the significant effect of stairs on the energy consumption of the flow. This will reduce the implementation costs of this type of overflow. Also, the recognition of the new technology of using rolled concrete materials and the compatibility of this construction method with the aforementioned overflow has led to the use of stair overflows in a large number of projects. The large amount of energy loss created by the stairs causes the excavation depth of the downstream relaxation basin, the length of the relaxation basin and the height of its side walls to be reduced, and in this sense, great economic savings are created in the construction of the dam (Chanson 2002). At the end, the amount of energy not consumed and remaining at the end of the overflow should be fully consumed by other energy consumers. The aim of this study is to find a combination of the number and width of stairs that minimizes the total cost of constructing a stair spillway and a depreciating structure downstream.

2. Research objectives

1) Determining an equation with a very small error to calculate the maximum consumption of energy according to the height of the overflow and the flow rate entering the stepped overflow.

2) Obtaining a program using the genetic algorithm, which calculates the geometric parameters of the overflow with any amount of optimal energy consumption that is given to the system by the expert and presents it as an output.

In this research, a method for optimizing the geometric parameters of the stepped overflow is presented. This method includes two separate steps:

1) Identifying the best formula for predicting the amount of energy consumption ($\Delta H/Ht$)

2) Optimizing the formula by genetic algorithm.

3. Extraction of laboratory results

In this step, we want to use the data that has been measured through the laboratory model to determine the amount of energy consumption. All the steps of the test were carried out in the hydraulic laboratory of Shahid Chamran University of Ahvaz by Mr. Siavash Heydari, who is in the following specifications. The flume used in the mentioned research is given.

4. Specifications of hydraulic laboratory flume

The length of the flume is 7 meters and its height is variable (1.4 meters in the initial 2.3 meters of the flume and 0.6 meters in the final 4.7 meters of the flume). According to the thickness of the flume wall, the useful width of the flume is 56 cm. This flume is designed in such a way that it has a closed system of water flow, so that water enters the flume from the beginning of the flume through a pipe from the top of the flume, and after passing through the length of the flume, it flows from its end into a final tank. At the end of this tank, a triangular overflow is installed in order to measure the flow rate. After passing through this overflow, the water is directed into the underground tank of the laboratory, from where it is returned to the flume by a centrifugal pump.

A vertical sliding valve is located at the end of the flume to control the depth of the downstream water and the place where the hydraulic jump is formed. Also, in order to measure the water depth in the flume, a graduated indicator equipped with a vernier with an accuracy of 0.1 mm was used. There is a flow control valve at the inlet of the flume feeding pipe, and two porous metal boxes are used to slow down the water flow at the beginning of the flume. A number of 54 models of stair overflows were made with 6 mm plexiglass sheet and experiments with 5 discharges (10-20-30-40-50 liters per second per unit width) and 3 slopes (h/l) (30, 56/ 26, 21.8 degrees) were performed (275 tests in total). In physical models with the same slope, the variable parameter was the number of stairs (or the height of the stairs). In Fig.1, the schematic of the flume in the hydraulic laboratory is presented.

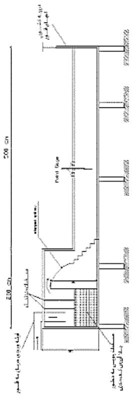


Fig. 1. schematic of the flume in the hydraulic laboratory

5. Determining the effective parameters in the flow through stepped overflows

According to the type of overflow and the studies done, the important and effective factors and parameters on the flow over the stepped overflows are as described in Table 1:

Table 1

Dimensional analysis table and unit of required parameters of this research

Dimensions based on mass system	unit	symbol	Variable	Row
$M.L^{-1}.T^{-1}$	$Kg/m.s$	μ	Dynamic viscosity	**1**
$M.L^{-3}$	Kg/m^3	ρ	Specific gravity of the fluid	**2**
$L.T^{-2}$	m/s^2	g	acceleration of gravity	**3**
L	m	y	depth of flow	**4**
$L.T^{-1}$	m/s	v	flow rate	**5**
L	m	H_{dam}	overflow height	**6**
L	m	l	Step progress	**7**
L	m	h	step height	**8**
---	---	**N**	number of steps	**9**

6. Evaluation of the information obtained from the laboratory model

6.1. First step assessment

In the first step, among the mentioned parameters, we selected six parameters N, L, H, q, Hdam and ΔH/Ht, four dimensionless parameters Yc/h, Yc/Hdam, h/L and N as input and ΔH/Ht is considered as output. Fig. 2 shows the frequency of all five input and output parameters.

In the following, the two-by-two diagram (1 to 4) of the input parameters compared to the output parameter ΔH/Ht is shown. The following graphs show the values of parameters Yc/h, Yc/Hdam, h/L and N in comparison with the output parameter ΔH/Ht.

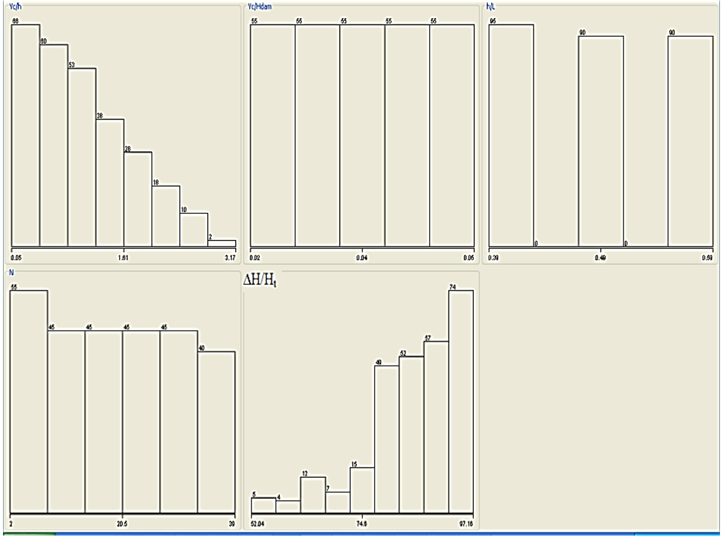


Fig. 2. frequency of five parameters Yc/h, Yc/Hdam, h/L and N and ΔH/Ht used

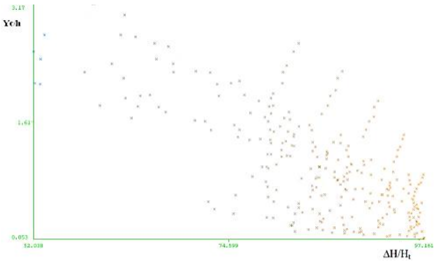


Diagram 1. Two-by-two diagram of input parameter Yc/h and output parameter ΔH/Ht

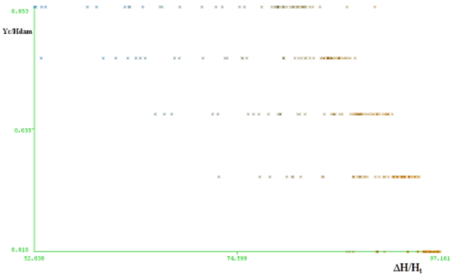
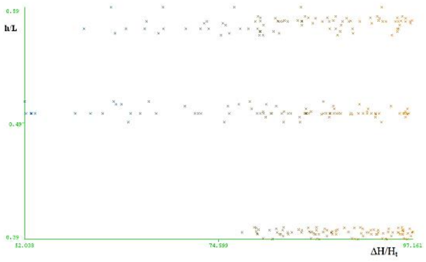


Diagram 2. Two-by-two diagram of input parameter Yc/Hdam and output parameter ΔH/Ht



Diagrams 3. Two-by-two diagram of input parameter h/L and output parameter ΔH/H

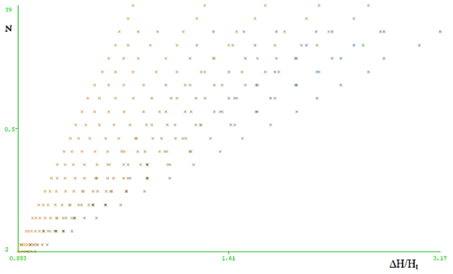


Diagram 4. Two-by-two diagram of input parameter N and output parameter ΔH/Ht

6.2. Evaluation of the second step

In this section, we use the IG method for feature selection due to its high accuracy and efficiency. As can be seen in Fig. 3, the parameters Yc/Hdam, Yc/h, h/L and N are effective on the output parameter ΔH/Ht, respectively. As can be seen in the mentioned figure, the parameter Yc/Hdam has the most influence on the output parameter ΔH/Ht.

6.3. Third step evaluation

In this section, we present the results of linear, tree, SVM-based and combined tree and linear regression methods for estimating ΔH/Ht.

Linear regression: Fig. 4, shows the results of linear regression to estimate ΔH/Ht based on Yc/Hdam, Yc/h, h/L and N parameters.

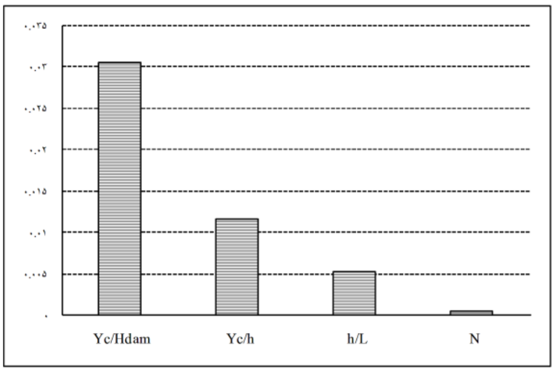
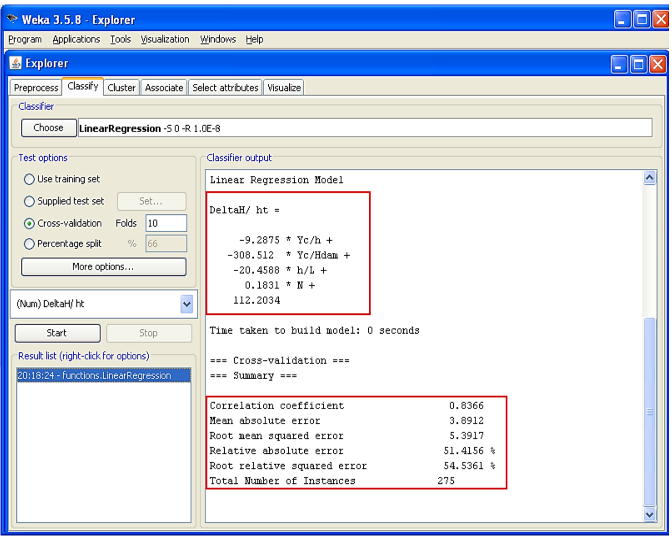


Fig. 3. Ranking the impact of input parameters on output



LinearRegression -S 0 -R 1.0E-8

○ Use training set
○ Supplied test set
● Cross-validation Folds 10
○ Percentage split % 66

(Num) DeltaH/ ht

20:18:24 - functions.LinearRegression

```
Linear Regression Model

DeltaH/ ht =

     -9.2875 * Yc/h +
   -308.512  * Yc/Hdam +
    -20.4588 * h/L +
      0.1831 * N +
    112.2034

Time taken to build model: 0 seconds

=== Cross-validation ===
=== Summary ===

Correlation coefficient                  0.8366
Mean absolute error                      3.8912
Root mean squared error                  5.3917
Relative absolute error                 51.4156 %
Root relative squared error             54.5361 %
Total Number of Instances              275
```

Fig. 4. Linear regression results on ΔH/Ht estimation

Tree regression: In Fig. 5, the ΔH/Ht prediction tree is shown based on Yc/Hdam, Yc/h, h/L and N parameters.

Regression based on SVM: In Fig. 6, the prediction function of ΔH/Ht based on SVM is displayed on the parameters Yc/Hdam, Yc/h, h/L and N.

Combined tree and linear regression:

In the following, the rules extracted by combined tree and linear regression to predict ΔH/Hta are presented.

If equation 1 is true:

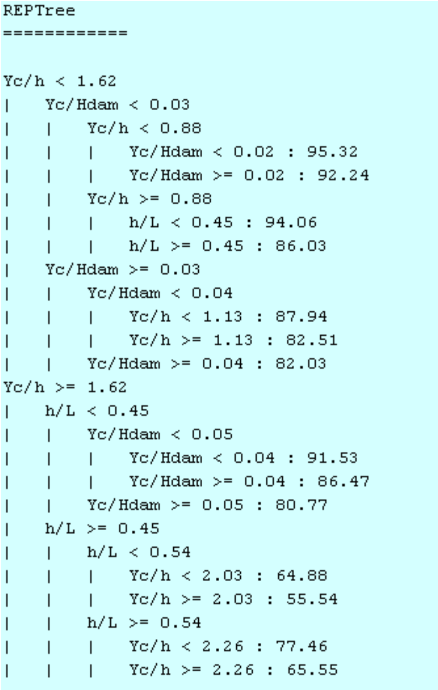
$$\frac{\Delta h}{H_t} = -0.639\left(Y_{\frac{c}{h}}\right) - 443.746\left(Y_{\frac{c}{H_{dam}}}\right) - 14.217\left(\frac{h}{1}\right) - 0.1056\ (N$$

If equation 2 holds true:

$$\frac{\Delta h}{H_t} = -814.28\left(Y_{\frac{c}{H_{dam}}}\right) + 55.5\left(\frac{h}{1}\right) - 1.119\left(N\right) + 108.198$$

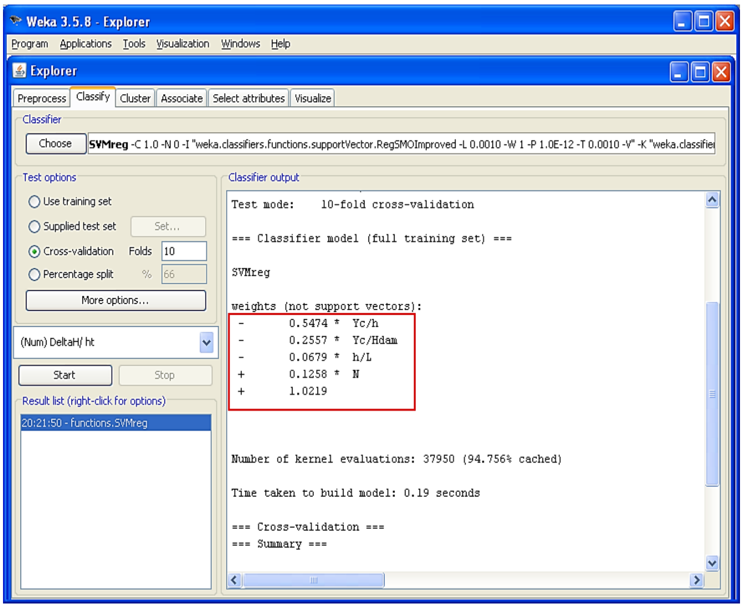
If the above two conditions are not met, equation 3 is met.

$$\frac{\Delta h}{H_t} = -814.28\left(Y_{\frac{c}{H_{dam}}}\right) + 55.5\left(\frac{h}{1}\right) - 1.119\left(N\right) + 108.19$$



```
REPTree
============

Yc/h < 1.62
|   Yc/Hdam < 0.03
|   |   Yc/h < 0.88
|   |   |   Yc/Hdam < 0.02 : 95.32
|   |   |   Yc/Hdam >= 0.02 : 92.24
|   |   Yc/h >= 0.88
|   |   |   h/L < 0.45 : 94.06
|   |   |   h/L >= 0.45 : 86.03
|   Yc/Hdam >= 0.03
|   |   Yc/Hdam < 0.04
|   |   |   Yc/h < 1.13 : 87.94
|   |   |   Yc/h >= 1.13 : 82.51
|   |   Yc/Hdam >= 0.04 : 82.03
Yc/h >= 1.62
|   h/L < 0.45
|   |   Yc/Hdam < 0.05
|   |   |   Yc/Hdam < 0.04 : 91.53
|   |   |   Yc/Hdam >= 0.04 : 86.47
|   |   Yc/Hdam >= 0.05 : 80.77
|   h/L >= 0.45
|   |   h/L < 0.54
|   |   |   Yc/h < 2.03 : 64.88
|   |   |   Yc/h >= 2.03 : 55.54
|   |   h/L >= 0.54
|   |   |   Yc/h < 2.26 : 77.46
|   |   |   Yc/h >= 2.26 : 65.55
```



SVMreg -C 1.0 -N 0 -I "weka.classifiers.functions.supportVector.RegSMOImproved -L 0.0010 -W 1 -P 1.0E-12 -T 0.0010 -V" -K "weka.classifie

○ Use training set
○ Supplied test set
● Cross-validation Folds 10
○ Percentage split % 66

(Num) DeltaH/ ht

20:21:50 - functions.SVMreg

```
Test mode:    10-fold cross-validation

=== Classifier model (full training set) ===

SVMreg

weights (not support vectors):
 -       0.5474 *  Yc/h
 -       0.2557 *  Yc/Hdam
 -       0.0679 *  h/L
 +       0.1258 *  N
 +       1.0219



Number of kernel evaluations: 37950 (94.756% cached)

Time taken to build model: 0.19 seconds

=== Cross-validation ===
=== Summary ===
```

Fig. 5. prediction tree ΔH/Ht

Fig. 6. prediction function based on SVM to predict ΔH/Ht

7. Evaluation of the second stage of the proposed method

In this section, we want to optimize the prediction function obtained in the previous section. Our goal is to identify the optimal value of other geometrical parameters such as Yc/h, h/L and N by giving the desired value of ΔH/Ht and Yc/Hdam. As seen in the previous section, the proposed estimation function of the linear and tree regression method obtained the best correlation coefficient and the least error, so at this stage we use this function as a fitness or target function. In the following table (3), the parameters of the genetic algorithm used are described.

Table 3

parameters used in the proposed genetic algorithm

The value of the parameter used in the evaluation of the proposed method of genetic	**algorithm parameters**
100	people in the audience
real number	real number data type of genes
Roulette cycle	Roulette cycle selection method
Gossin	Gaussian mutation function
single point	Single point intersection function
After producing 1000 generations	final conditions

8. Operators

In the evaluation of the proposed method, two Gaussian jump operators and one-point intersection operator have been used. In fig. 7 & Fig. 8 shown An example of applying a mutation and single point intersection operator in the proposed method.

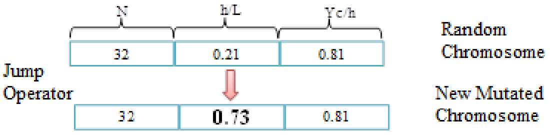


Fig. 7. An example of applying a mutation operator in the proposed method

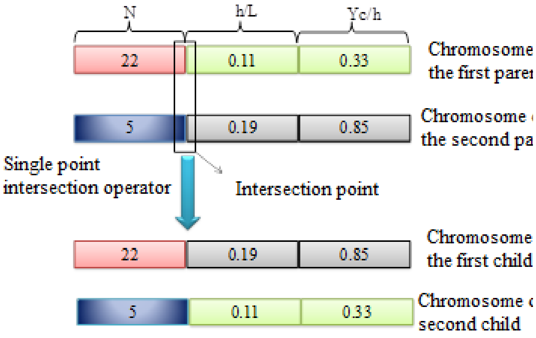


Fig. 8. An example of applying a single point intersection operator in the proposed method

9. Fitness function

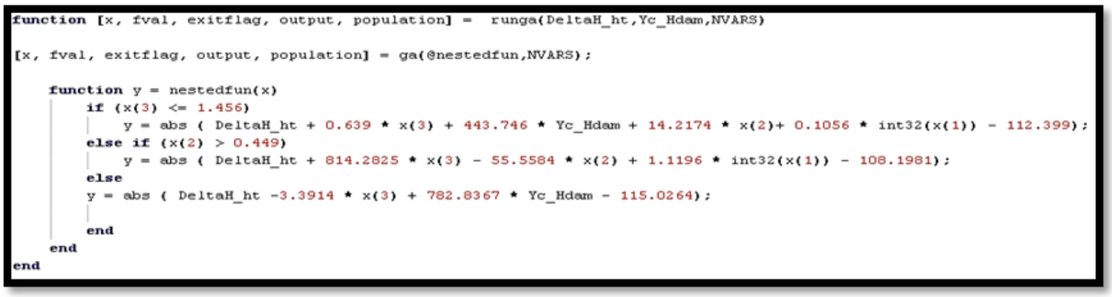
In the following, the code of the fitness function, which is actually the same as the linear combined regression, is displayed. It should be noted that the chromosome in this code (shown in fig .9) is displayed using the vector x and the fitness function is also called nestedfun. As you can see, for the x1 variable (N parameter), we have used the Int32 command to convert this variable into an integer. As can be seen, our proposed fitness function is in the form ((regression formula Y=ABS (ΔH/Ht -)). Because our goal is that by giving the desired value of ΔH/Ht, the difference between the regression output and ΔH/ Ht reaches its lowest state. In this case, the regression parameters that cause the minimization of this fitness function are considered as optimal parameters.

Evaluations: To evaluate and validate the proposed method, we determine the value of Yc by using different flow rates (q) and by giving the desired value of Hdam and ΔH/Ht, from the proposed genetic algorithm, the optimal geometric parameters of Yc/h, h We request /L and N. After identifying these three parameters from them and given Yc, we extract three parameters h, L and N. In this section, as the first evaluation, we use the flow parameter equal to 0.01, the Hdam parameter equal to 1.2, and the ΔH/Ht parameter equal to 90%.

Given parameters:

q	H_{dam}	Yc	Yc/H_{dam}	ΔH/H_t
0.01	1.2	0.0215	0.0181	**90**

By implementing the proposed genetic algorithm, a random population is first generated and minimizes the fitness function in each generation. In fig .10, the trend of movement of the best chromosome (Best Fitness) and the average value of the fitness function of all members of the population are shown. As can be seen in the fig. 10, the individuals of the population gradually move towards the best chromosome in each generation until in the 1000th generation, all chromosomes converge to an optimal point. In the diagram (6), the distance between the members of the population in the generation is also shown, as can be seen, at the beginning of the evolution of the proposed genetic algorithm, the chromosomes have a significant distance from each other, but gradually when they tend to the optimal point, the distance between the chromosomes of the population decreases a lot and becomes close to zero.



```
function [x, fval, exitflag, output, population] =  runga(DeltaH_ht,Yc_Hdam,NVARS)

[x, fval, exitflag, output, population] = ga(@nestedfun,NVARS);

    function y = nestedfun(x)
        if (x(3) <= 1.456)
            y = abs ( DeltaH_ht + 0.639 * x(3) + 443.746 * Yc_Hdam + 14.2174 * x(2)+ 0.1056 * int32(x(1)) - 112.399);
        else if (x(2) > 0.449)
            y = abs ( DeltaH_ht + 814.2825 * x(3) - 55.5584 * x(2) + 1.1196 * int32(x(1)) - 108.1981);
        else
        y = abs ( DeltaH_ht -3.3914 * x(3) + 782.8367 * Yc_Hdam - 115.0264);

        end
    end
end
```

Fig. 9. Fitness function code

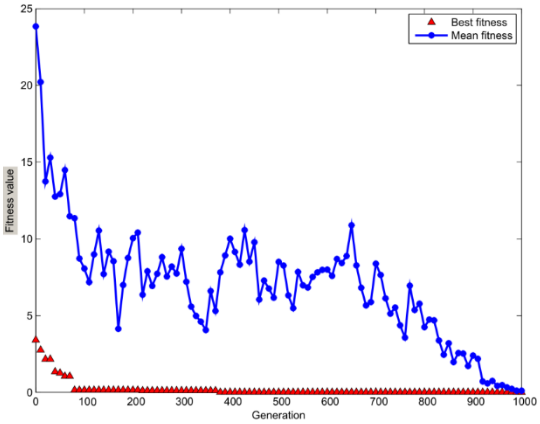


Diagram (5): The evolution diagram of population
individuals in the generations of
the proposed genetic algorithm

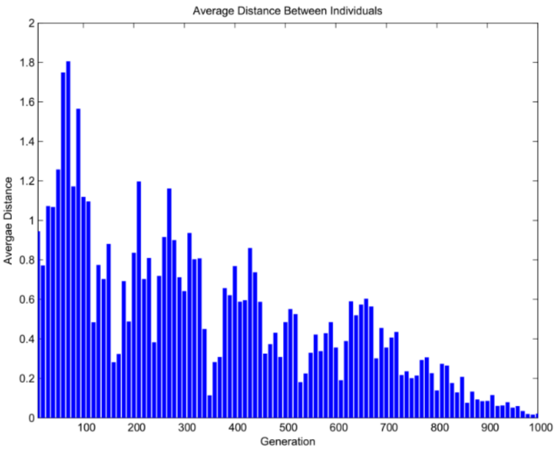


Diagram (6): The diagram of the distance between the individuals of the population in the proposed genetic algorithm

When the proposed genetic algorithm moves to an optimal point for the given parameters Yc/Hdam equal to 0.0181 and ΔH/Ht equal to 90 and stops there, our algorithm ends. The output of the proposed genetic algorithm can be seen in the table below.

As seen in table number (4), the difference between the given ΔH/Ht and the regression formula used at the optimal point found is very very small (0.00008). The chromosome that obtained this optimal value is shown in the table below. In the following, we have calculated the amount of two parameters h and L separately using the given value of Yc:

H	L
0.0388651704176774	0.04288690411356

To evaluate the proposed method, because we have laboratory results for Yc/Hdam equal to 0.0181 and ΔH/Ht equal to 90, we have done this evaluation so that we can compare the results obtained by the proposed method with the results obtained in the laboratory. Let's make a comparison. In table (5), the laboratory results for flow rate equal to 0.01 and Hdam equal to 1.2 are displayed and in that parameters N, Yc/h, h/L and ΔH/Ht are measured in four different modes. In this table, based on the regression formula used (linear and tree combination), the goodness-of-fit function has been calculated on each of these four laboratory data.

As can be seen in table (5), none of the laboratory data could bring the value of the fitness function below 1. Here, the importance and accuracy of the proposed method is more revealed, which has been able to minimize the fitness function and, as a result, be more optimal.

10. Results and discussion

As can be seen from the evaluation of the previous two sections, first we extracted the best among the regression methods that had the highest correlation coefficient. The more accurate regression method in this thesis is the combined linear and tree regression method, which has been able to increase the correlation coefficient to more than 0.94. In the second step of the proposed method, we proposed a genetic algorithm to optimize the selected regression function. The evaluations show that our proposed

Table 4

Output of the proposed genetic algorithm for data parameters

N	h/L	Yc/h	Fitness function value
17	0.912113709472540	0.557967359617298	**0.0000831841496591323**

Table 5

measured laboratory data

	N	h/L	Yc/h	Yc/H_{dam}	$\Delta H/H_t$	Fitness function value
1	33	0.567568	1.032643	0.0181	90	2.1665
2	35	0.571429	1.084275	0.0181	90	1.8674
3	25	0.507692	0.657136	0.0181	90	4.1025
4	27	0.5	0.72285	0.0181	90	3.9587

Table 6

Output of the proposed genetic algorithm for geometric parameters for q=0.01 m2/s

	N	h/L	Yc/h	Delta	h	NH	Fitness
0.01	89	0.58	2.765366	85	0.007956	0.708044	0.000010961
0.01	57	0.58	1.793144	88	0.012269	0.69933	0.993787164
0.01	50	0.58	1.385675	90	0.015877	0.793837	0.000033413
0.01	9	0.58	0.282789	95	0.077797	0.700169	0.034377889
0.01	2	0.58	0.05	97	0.44	0.88	1.077670000

It is meaningless for more than 95%

Table 7

Output of the proposed genetic algorithm for geometric parameters for q=0.01 m2/s

q	N	h/L	Yc/h	Delta	h	NH	Fitness
0.01	98	0.5	3.057975	85	0.007194	0.705042	0.000026267
0.01	77	0.5	1.833574	88	0.011998	0.923879	0.000018074
0.01	61	0.5	1.347859	90	0.016322	0.995653	0.000009803
0.01	19	0.5	0.463957	95	0.047418	0.900946	0.000003498
0.01	11	0.5	0.242019	96	0.090902	0.999922	0.003378014
0.01	3	0.5	0.066043	97	0.333116	0.999348	0.056129527

It's meaningless to more than 96% ---

method, we proposed a genetic algorithm to optimize the selected regression function. The evaluations show that our proposed method works much more accurately than the laboratory results and can identify the optimal geometrical parameters N, h and L by giving the desired Yc/Hdam and ΔH/Ht. In the following, by placing the depreciation of different energies in the proposed program, the number of steps corresponding to each energy depreciation has been obtained according to the tables and diagrams below.

According to table (6), for q=0.01 m2/s and a small slope, energy consumption is possible up to 95%. And bigger than that is meaningless because of the high fitness number that the program gives.

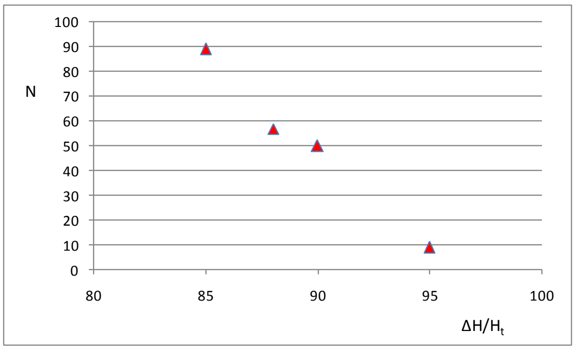


Diagram 7. The output of the proposed genetic algorithm for q=0.01 m2/s

Table 8

Output of the proposed genetic algorithm for geometric parameters for q=0.01 m2/s

q	N	h/L	Yc/h	Delta	h	NH	Fitness
0.01	110	0.4	3.299916	85	0.006667	0.733352	0.000034515
0.01	86	0.4	2.571196	88	0.008556	0.735844	0.000017533
0.01	70	0.4	2.085514	90	0.010549	0.738427	0.000031551
0.01	30	0.4	0.871012	95	0.025258	0.757739	0.000035290
0.01	14	0.4	0.385312	97	0.057097	0.799351	0.000002683

It made sense for 97% but not 98%

Table 9

Output of the proposed genetic algorithm for geometric parameters for q=0.02 m2/s

q	N	h/L	Yc/h	Delta	h	NH	Fitness
0.02	114	0.58	3.514654	77	0.00626	0.713584	0.0000102732
0.02	90	0.58	2.786091	80	0.007896	0.710673	0.0000384104
0.02	50	0.58	1.571404	85	0.014	0.700011	0.0001469038
0.02	10	0.58	0.314225	39	0.070013	0.700135	0.0274841438
0.02	2	0.58	0.050017	94	0.439849	0.879699	2.9588869448

It is meaningless for more than 93%

Table 10

Output of the proposed genetic algorithm for geometric parameters for q=0.02 m2/s

q	N	h/L	Yc/h	Delta	h	NH	Fitness
0.02	123	0.5	3.807243	77	0.005778	0.710751	0.000038009
0.02	99	0.5	3.078614	80	0.007146	0.707461	0.000031776
0.02	59	0.5	1.854165	85	0.011865	0.700046	0.006454728
0.02	20	0.5	0.484665	90	0.045392	0.907843	0.000034964
0.02	12	0.5	0.264106	91	0.0833	0.9996	0.014297569
0.02	2	0.5	0.05	94	0.44	0.88	1.821484000

It is meaningless for more than 91%.

Table 11

Output of the proposed genetic algorithm for geometric parameters for q=0.02 m2/s

q	N	h/L	Yc/h	Delta	h	NH	Fitness
0.02	134	0.4	4.211308	77	0.005224	0.70002	0.001980163
0.02	110	0.4	3.457143	80	0.006364	0.7	0.00182917156
0.02	74	0.4	1.628032	85	0.013513	0.99998	0.00113064290
0.02	32	0.4	0.726438	90	0.030285	0.969113	0.00001237970
0.02	7	0.4	0.163114	89	0.134875	0.944126	0.00002374533
0.02	2	0.4	0.050122	94	0.438932	0.877864	0.39982172718

It is meaningless for more than 93%.

Table 12

Output of the proposed genetic algorithm for geometric parameters for q=0.02 m2/s)

q	N	h/L	Yc/h	Delta	h	NH	Fitness
0.03	172	0.58	4.894208	66	0.004495	0.773159	0.000038716
0.03	97	0.58	3.048506	75	0.007217	0.700015	0.009936478
0.03	58	0.58	1.822828	85	0.012069	0.700011	0.000973029
0.03	19	0.58	0.444708	90	0.049471	0.939943	0.000008329
0.03	2	0.58	0.05	91	0.44	0.88	3.952590000

For more than 90% it was meaningless.

Table 13

Output of the proposed genetic algorithm for geometric parameters for q=0.03 m2/s

q	N	h/L	Yc/h	Delta	h	NH	Fitness
0.03	182	0.5	4.999964	66	0.0044	0.800806	0.013774911
0.03	107	0.5	3.331363	75	0.006604	0.706618	0.000010846
0.03	68	0.5	1.951718	85	0.011272	0.766504	0.000004189
0.03	28	0.5	0.7373	90	0.029839	0.835481	0.000017425
0.03	2	0.5	0.05	91	0.44	0.88	1.815198000

For more than 90% it was meaningless.

Table 14

Output of the proposed genetic algorithm for geometric parameters for q=0.03 m2/s

q	N	h/L	Yc/h	Delta	h	NH	Fitness
0.03	158	0.4	4.952886	66	0.004442	0.701813	0.000002449
0.03	118	0.4	3.708515	75	0.005932	0.700011	0.001951064
0.03	79	0.4	2.358792	85	0.009327	0.736818	0.000023628
0.03	40	0.4	0.979155	90	0.022468	0.898734	0.000011975
0.03	2	0.4	0.05	91	0.44	0.88	0.393458000

For more than 90% it was meaningless.

In this amount of energy consumption, the number of 9 steps is the answer.

And the graph (7) of proportional values of the number of steps with the corresponding energy consumption is given for table (5-22).

According to table (8), for q=0.01 m2/s and a small slope, energy consumption is possible up to 97%. And bigger than that is meaningless because of the high fitness number that the program gives. In this amount of energy consumption, the number of 14 stairs is the answer, and the graph (9) of the proportional values of the number of stairs and the corresponding energy consumption is given for table (5-24).

According to table (9), for q=0.02 m2/s and a small slope, energy consumption is possible up to 93%. And bigger than that is meaningless because of the high fitness number that the program gives. In this amount of energy consumption, the number of 14 stairs is the answer, and the graph (10) of the proportional values of the number of stairs and the corresponding energy consumption is given for table (5-25).

According to table (10) for q=0.02 m2/s) and a small slope, energy consumption is possible up to 91%. And bigger than that is meaningless because of the high fitness number that the program gives. In this amount of energy consumption, the number of 12 steps is the answer.

And the graph (11) of the proportional values of the number of steps with the corresponding energy consumption is given for the table (5-26).

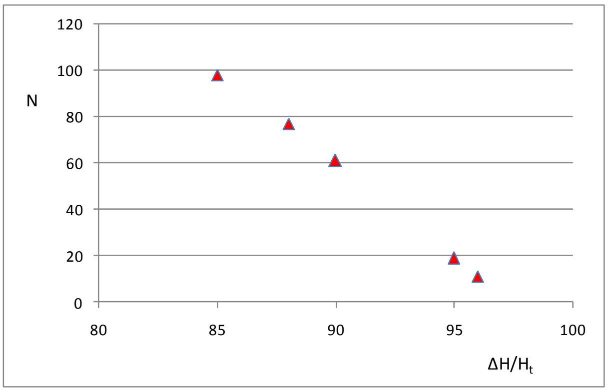


Diagram (8): The output of the proposed genetic algorithm for q=0.01 m2/s

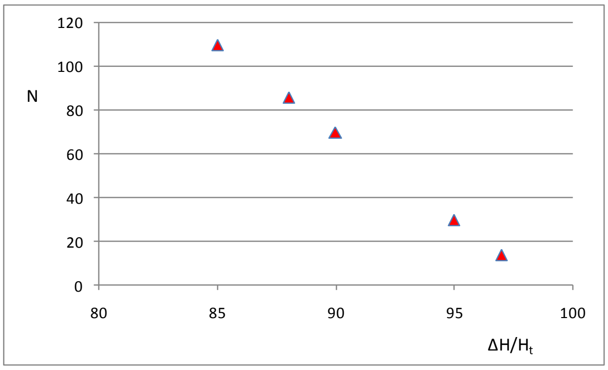


Diagram (9): The output of the proposed genetic algorithm for q=0.01 m2/s

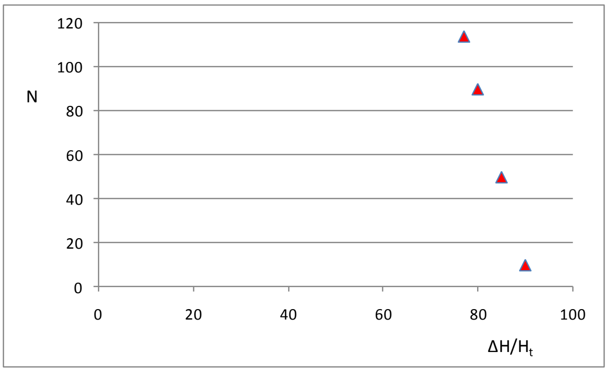


Diagram (10): The output of the proposed genetic algorithm for q=0.02 m2/s

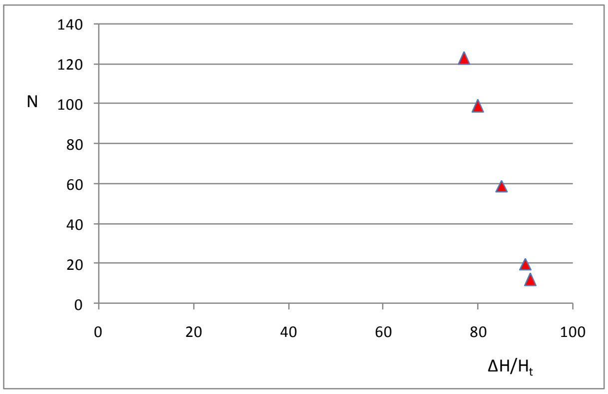


Diagram (11): The output of the proposed genetic algorithm for q=0.02 m2/s

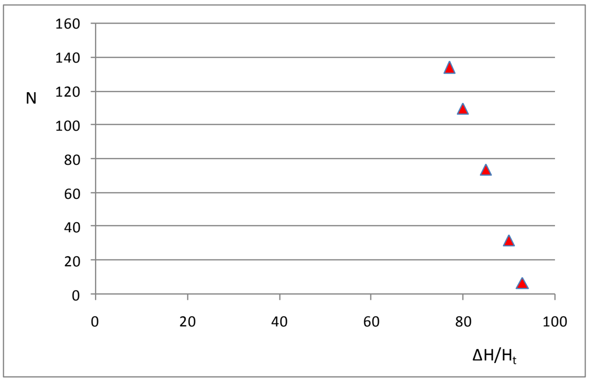


Diagram (12): The output of the proposed genetic algorithm for q=0.02 m2/s)

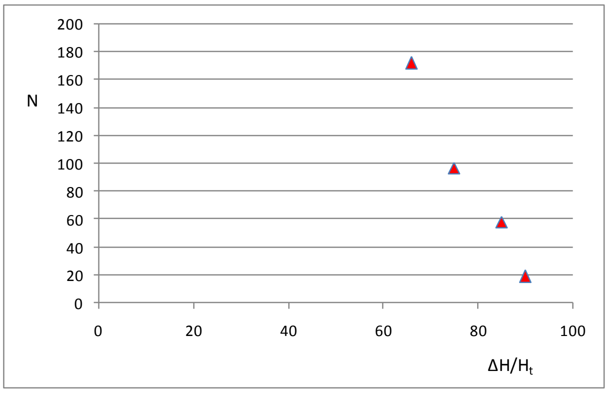


Diagram (13): The output of the proposed genetic algorithm for q=0.03 m2/s)

According to table (11), for q=0.02 m2/s) and a small slope, energy consumption is possible up to 89%. And bigger than that is meaningless because of the high fitness number that the program gives.

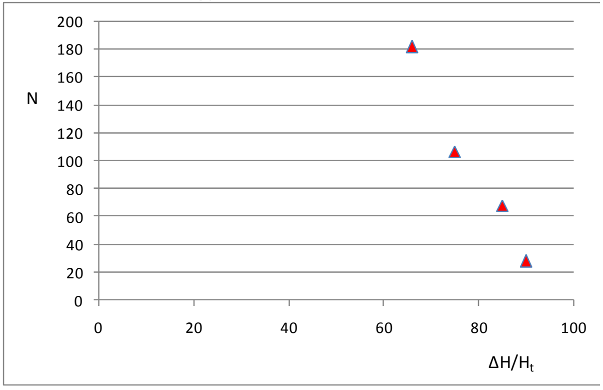


Diagram (14): The output of the proposed genetic algorithm for q=0.03 m2/s)

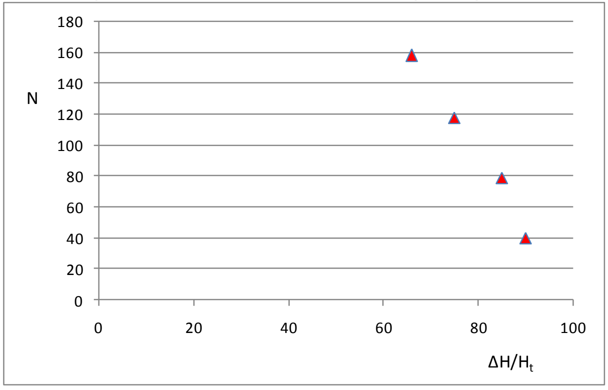


Diagram (15): The output of the proposed genetic algorithm for q=0.03 m2/s)

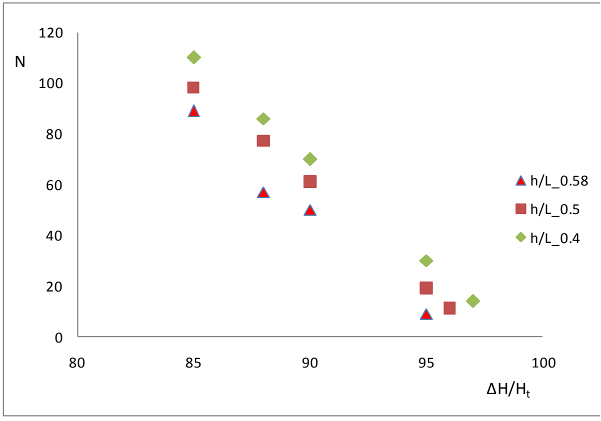


Diagram (16): Output of the proposed genetic algorithm for q=0.01 m2/s)

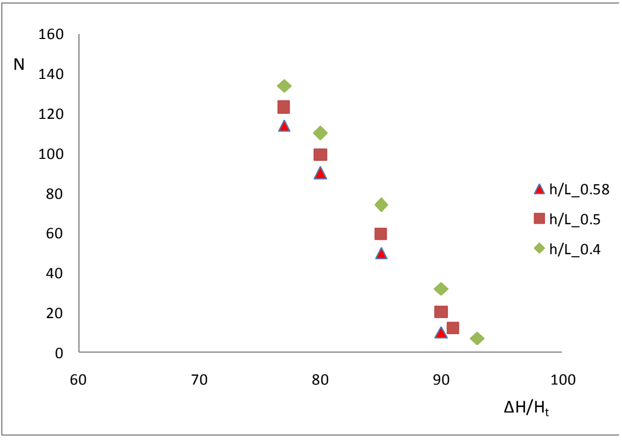


Diagram (17): Output of the proposed genetic algorithm for q=0.02 m2/s; For q equal to 0.03

In this amount of energy consumption, the number of 7 stairs is the answer, and the graph (12) of the corresponding values of the number of stairs and the corresponding energy consumption is given for table (5-27).

According to table (12), for q=0.03 m2/s) and a small slope, energy consumption is possible up to 90%. And bigger than that is meaningless because of the high fitness number that the program gives. In this amount of energy consumption, the number of 19 stairs is the answer, and the graph (13) of the proportional values of the number of stairs and the corresponding energy consumption is given for table (5-28).

According to table (13), for q=0.03 m2/s) and a small slope, energy consumption is possible up to 90%. And bigger than that is meaningless because of the high fitness number that the program gives. In this amount of energy consumption, the number of 28 stairs is the answer, and the graph (14) of the proportional values of the number of stairs with the corresponding energy consumption is given for table (5-29).

According to table (14), for q=0.03 m2/s) and a small slope, energy consumption is possible up to

90%. And bigger than that is meaningless because of the high fitness number that the program gives. In this amount of energy consumption, the number of 40 stairs is the answer, and the graph (5-15) of the proportional values of the number of stairs with the corresponding energy consumption is given for table (5-30).

In diagrams 16, 17 and 18, the amount of energy consumption according to the number of steps corresponding to it for each constant flow rate and in 3 different slopes in each of the graphs is given for their comparison.

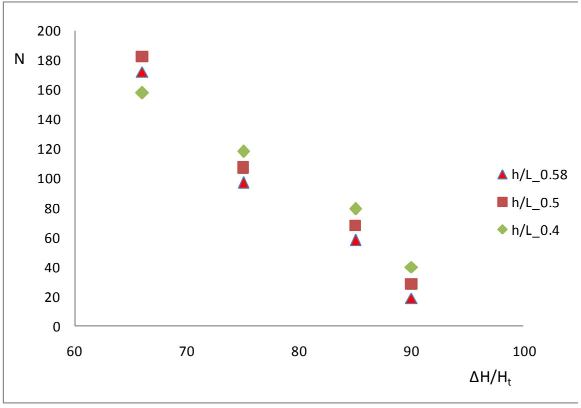


Diagram (18): Output of the proposed genetic algorithm for q=0.03 m2/s)

11. Conclusions

The results obtained from the analyzes performed in this study are as follows:

1) With the increase in flow rate, the amount of maximum energy consumption decreases.

2) By increasing the slope of the small head at a constant flow rate, the number of optimal steps for equal energy consumption increases.

3) From the very high number of steps that results in low energy consumption, we come to the conclusion that the effect of the existence of the step is reduced in the high step and the small head is inclined towards the smooth bottom head, which makes the percentage Reduce its energy loss.

References

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[2] Chanson, H. (2001) . "The hydraulics of stepped chutes and spillways". Balkema, Lisse, The Netherlands, 418 pages.

[3] Chanson, H. and Gonzalez, C.A. (2004). "Stepped Spillways for Embankment Dams: Review, Progress and Development in Overflow Hydraulics". Proceedings of the International Conference on Hydraulics of Dams and River Structures, Tehran, Iran, Balkema Publ., The Netherlands,287–294.