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Seismic Analysis of Homogeneous Earth Dam and Optimization of Its Parameters Using Cuckoo

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Absract
Dynamic behavior considering the interaction between the foundation -body of the homogeneous earth dam (Iran) under the record of the Manjil earthquake is investigated in this paper.Modeling the finite element model under earthquake response in modeling the geotechnical problem has been modeled with plaxis software to determine the height and extent of the lateral foundation in the dam is modeled.In this research, the dam heights and the foundation widths has been chosen cuckoo optimization algorithm (COA) method.

Keywords: Dynamic analysis, Homogeneous earth dam, Manjil Earthquake, Foundation width, Dam height, Cuckoo optimization algorithm.

INTRODUCTION

In the recent period, the finite element method is the preferred method for choice for solving wave propagation through bounded and unbounded elastodynamic problems. improvements and Development use dam-foundation coupled model of these methods to study dynamic behavior of earth dams; revealed various aspects of dam response to seismic loads[1,2].

The leveling of the earth's surface and the structure were fixed by the assumptions suggested in the dynamic analysis. The base motion represents the ground motion anticipated at the proposed site and is influenced by the nature and extent of the soil deposit at the site[3].

(Ambraseys1960)extended previous work for dams on rigid foundations to dams on flexible foundations, but did not discuss the aspects of interaction [4].(Chopra and Perumalswami 1969) presented an analysis for dams on a semi-infinite medium subject to periodic excitations.[5]

Damping and Elastic Modulus of foundation soils to the Elastic Modulus were considered in the research of the effect of interaction.Their research affects both damping and the ratio of the elastic modulus of foundation soils to elastic modulus of the dam as they affect interaction.[6] In studying the seismic response of a dam with a flexible foundation, the finite element method has been used.

(Anisheh 2012) For cases where the interaction is strong, the soil and structure systems should be analyzed together using a coupled system researches have been conducted, dynamic analysis of Narmab earth dam (Iran) considering dam-foundation coupled model with various foundation widths (B) and dam heights (H) under horizontal component of Manjil earthquake has been performed using the Plaxis program. The B / H ratio was calculated using the PSO algorithm method of 1.29 [7]. In the previous work, B/H ratio has been adjusted experimentally.To optimize this research, the NLEO theoretical basis has been used [8].

In this study dynamic analysis of Homogeneous earth dam (Iran) considering dam-foundation interaction, under Manjil earthquake (after scaling to a max =0.28g), as input motion, carried out by Plaxis. For a precise study of the effect of dam height and width of the foundation in finite element model, on the calculated earthquake responses, several dam-foundation coupled models have been solved with Plaxis, a finite element software for solving geotechnical problems. In addition, heights of dam (30,60,90) meters and widths of foundation (50,100,200) meters affect on the displacement of the dam. In order to minimize displacement of dam, COA algorithm is used.

Homogeneous Earth Dam

Homogeneous earth dam, which is under construction, is located 5 km south of Minoodash-Iran. It is constructed on the route of the Narmab River in order to provide agricultural and drinking water. Figure 1, the cross section shows a non- foundation dam with a height of 60 meters. In Fig. 2, the cross section of the body of the dam-foundation coupled model to a height of 60 meters and a depth of from the bed of the river to the bedrock of 65 meters fixed in the calculations.Dam site located in Alborz Active fault zone.

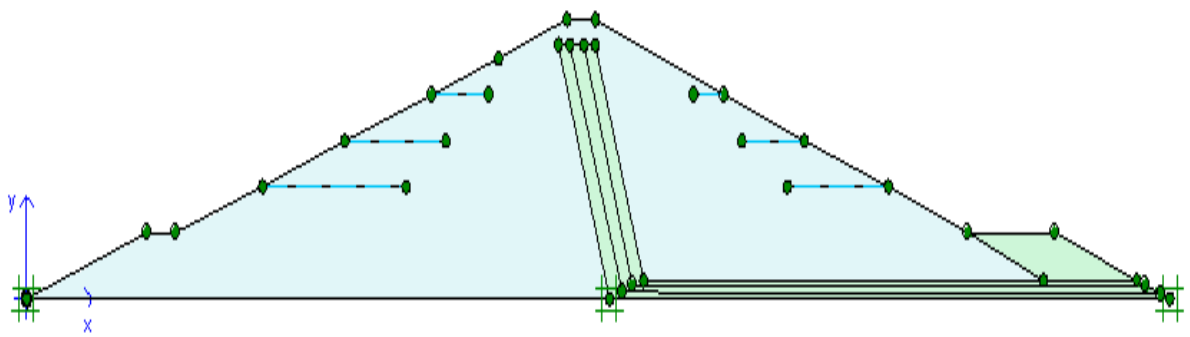

Fig .1.Typical section of Dam without foundation

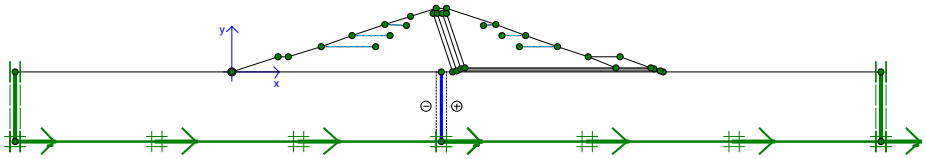

Fig. 2. Typical section of the dam-foundation coupled model

Dynamıc Analysıs

The numerical modelling for the dynamic analyses has been performed using the PLAXIS program, which are based on finite element method.In Fig.3, the elementalization of a homogeneous earth dam shows a rigid foundation.Figure 4 shows the geometry of the dam-foundation couple model of the Homogeneous earth dam[9].Table 1 Specifications of homogeneous earth dam materials are used in dynamic analysis with Mohr Coulomb (Elasto-Plastic) model.

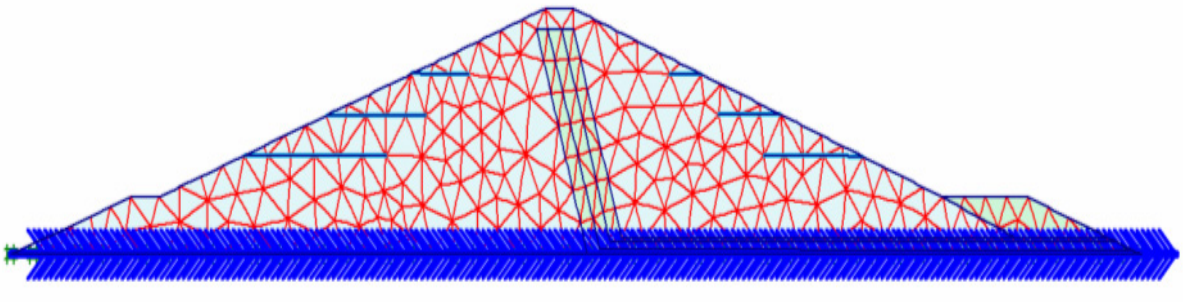

Fig .3. model of dam with rigid basement and its elements

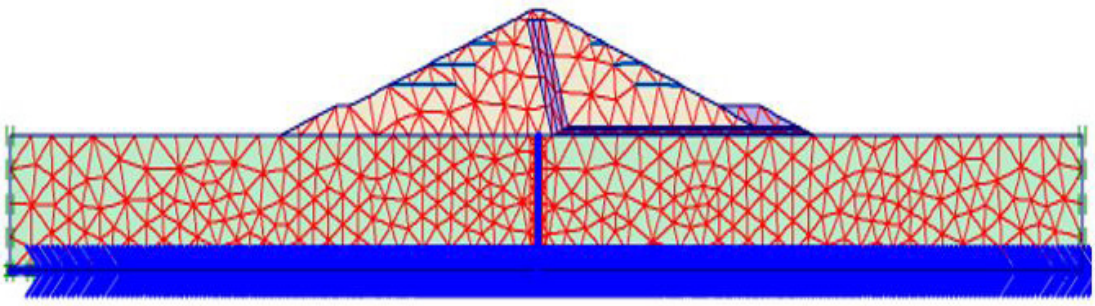

Fig .4.model of dam-foundation and its elements

Table 1. Material properties of the Homogeneous earth dam

Type of material	γ_{sat} (KN/m³)	C (KPa)	φ	E (MPa)	υ	K_x, K_y m/day
Dam body	21	28	23	214.6	0.3	8.64E -7
foundation	21	0.5	41	267	0.3	0.864
Drain material	20.7	0.5	42	348	0.25	86.4

The manjil earthquake has been the basis of dynamical analysis. Figure 5 shows the time history of Manjil earthquake acceleration,were normalized to a maximum acceleration of 0.28g which has been considered inaccordance with Maximum Design Level (MDL).

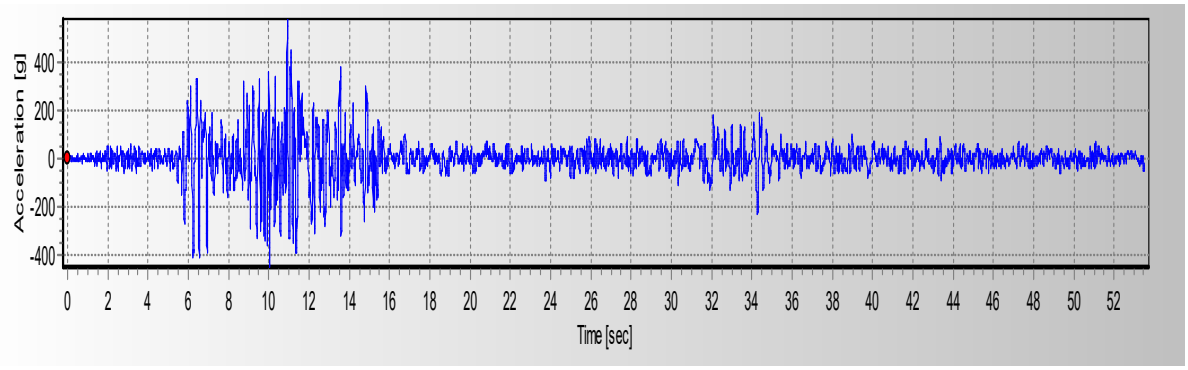

Fig. 5.Normalized horizontal component time history of Manjil earthquake

The Proposed Cuckoo Optımızatıon Algorıthm (Coa)

Figure 6 Cuckoo Bird Flowchart is provided .This algorithm starts with a small number of cuckoo birds, as is the case with other methods.A small number of cuckoos birds that are capable of laying eggs are embedded in the nest of other host birds. If the eggs embedded are like host eggs, they are likely to grow.The remaining eggs identified by the host bird are deleted. Eggs that have a chance of growing indicate the proper conditions for nests in that area.Eggs that grow have shown a high level of profit in the position. Consequently, more eggs grow in this area, indicating that COA is optimized.

The best location for growing egg numbers is selected by the cuckoo bird.After the chicks survived and their growth began to mature, they formed a group. Naturally, groups choose their own habitat.The best position to survive is the destination of all cuckoo groups. Immigration to the best place of residence is carried out by Cuckoo bird groups. Each group locates near its best range.

Based on the number of cuckoo birds and the distance between each cuckoo bird from the best location(best habitat),the number of radius of laying is formed.After that, the random laying in the nest begins from the range of the ovulation radius. This step will continue to reach the best place for the most laying and most of the cuckoo population is gathered around the same position.[10].

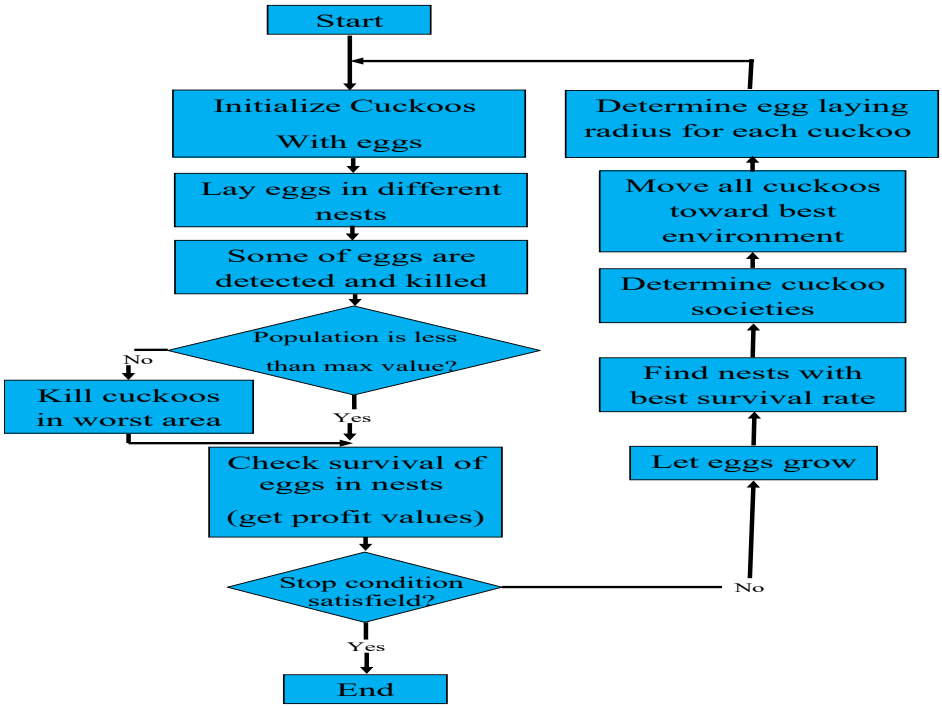

Fig. 6. Flowchart of the COA [10]

Generatıng Inıtıal Cuckoo Habıtat

In order to optimize the issues, the values of the variables must be arranged in the form of an array.In PSO and GA terminologies this array is called and "Particle Position",and "Chromosome" respectively. In the Cuckoo Optimization (COA) algorithm, this statement is called "habitat". In a N_{var}-dimensional optimization issue, a habitat is an array of $1 \times N_{var}$, indicating the location of the cuckoo bird's habitat.The array is defined as follows:

$$\text{Habitat} = [Y_1, Y_2, ..., Y_{Nvar}] \quad (1)$$

The values of the variable $(Y_1, Y_2, ..., Y_{Nvar})$are the number of floating points. The profit value of an existing habitat is obtained by evaluating the FP earnings function in the habitat $(Y_1, Y_2, ..., Y_{Nvar})$.as a result:

$$\text{Profit} = fp(\text{habitat}) = fp(Y_1, Y_2, ..., Y_{Nvar}) \quad (2)$$

A negative sign is multiplied by the cost function, then the COA is minimized:

$$\text{Profit} = -\text{Cost}(\text{habitat}) = -fc(Y_1, Y_2, ..., Y_{Nvar}) \quad (3)$$

To begin the optimization algorithm, a $N_{pop} \times N_{var}$-dimensional matrix is generated. Then, for each of these habitats, a random number of eggs cuckoo is allocated. Typically, each bird cuckoo lays 5 to 20. This minimum and maximum allocation of cuckoo bird eggs is used in repeated replies.

Another habit of cuckoo bird is that they lay eggs on a specific range, which is called the maximum range of laying "Egg Laying Radius (ELR)". In an optimization problem, each variable has a higher varhi and a lower varlow limit, each of which (ELR) is defined by these limits. (ELR) Relates to the whole cuckoo bird's egg, number of current cuckoo's eggs and also variable limits of var_{hi} and var_{low}. so ELR is defined as follows:

$$ELR = \alpha \times \frac{\text{Number of current cuckoo's eggs}}{\text{Total number of eggs}} \times (var_{hi} - var_{low}) \quad (4)$$

α is the variable that the maximum ELR value is set to. [10].

Cuckoos' Style For Egg Layıng

Each cuckoo randomly places eggs in the host nest located in its ELR.See Figure 7. When all the bird cuckoo put their eggs, some eggs that are not similar to host eggs are identified and thrown out of the nest. In normal mode, the cuckoo bird is destroyed if the value of the profit function is less than 10% after the laying of the egg.The rest of the chicks nourish and grow in the host nests. The interesting thing about the cuckoo chickens is that only one egg per nest can grow.When the cuckoo chickens come out of the egg, the host bird throws its eggs out. If the host chickens are removed earlier than eggs, then the cuckoo's chicken will eat most of the food that the host bird has eaten (The cuckoo chicken body is 3 times bigger And it can put the rest of the host chick off). After a few days the cuckoo bird live, and host chicks die from starvation [10].

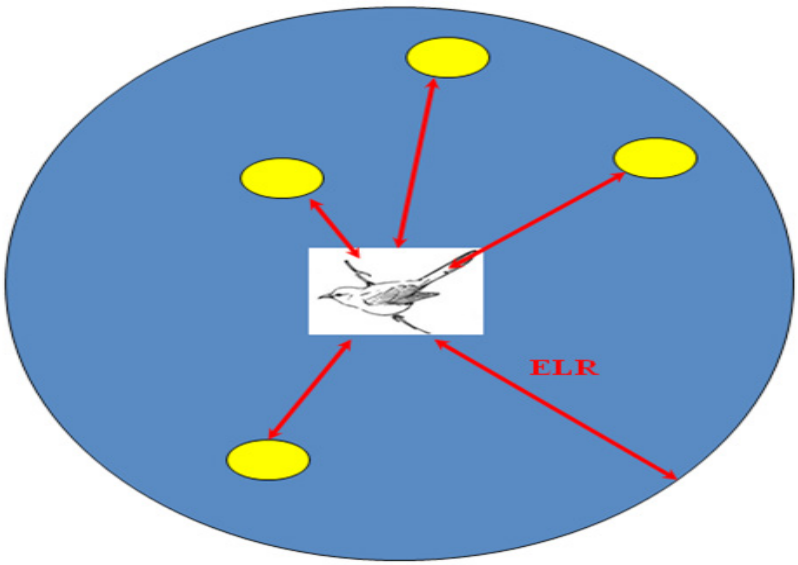

Fig .7. Random egg laying in ELR, central red star is the initial habitat of the cuckoo with 5 eggs; pink stars are the eggs' new nest [10]

Immıgratıon Of Cuckoos

When the cuckoo chicken grows to the mature stage, they live for some time around and around their group. With the arrival of laying time, the migration of the cuckoo bird to the place where it has a greater chance of surviving its eggs. Once the cuckoo bird groups are formed in nature, the node selects the best position as the destination for other cuckoos for migration. It is difficult to recognize which cucukoo belongs to which group belongs to the cuckoo bird in the environment.

The solution to this problem is the grouping of bird creatures by the K-means classification method (a k of 3–5 seems to be sufficient in simulations).

Now that the cuckoo group was formed, the average profit of the group is calculated to determine the relative optimality of the habitat. Then the group with the highest average (optimality) is selected as the target group and other groups migrate to it. Figure 8 shows the migration of the cuckoo bird toward the goal habitat.

As it is seen in Fig. 8,each cuckoo only flies ,λ % of all distance toward goal habitat and also has a deviation of ϕ radians.These two parameters are the Cuckoo Bird Guide for more environment searching.

For each cuckoo, ϕ and λ are defined as follows:

$$\lambda \sim U(0, 1)$$
$$\lambda \sim U(-\omega, \omega) \quad (5)$$

λ The random number is between 0 and 1.

The parametric ω represents the amount of deviation from the target point. An ω between π/ 6 and - π / 6 (radians). Each bird of the cuckoo owns a number of eggs, after

migrating to the destination of the target and determining their habitat. In terms of the number of birds, each ELR cuckoo bird is identified, and then the laying begins [10].

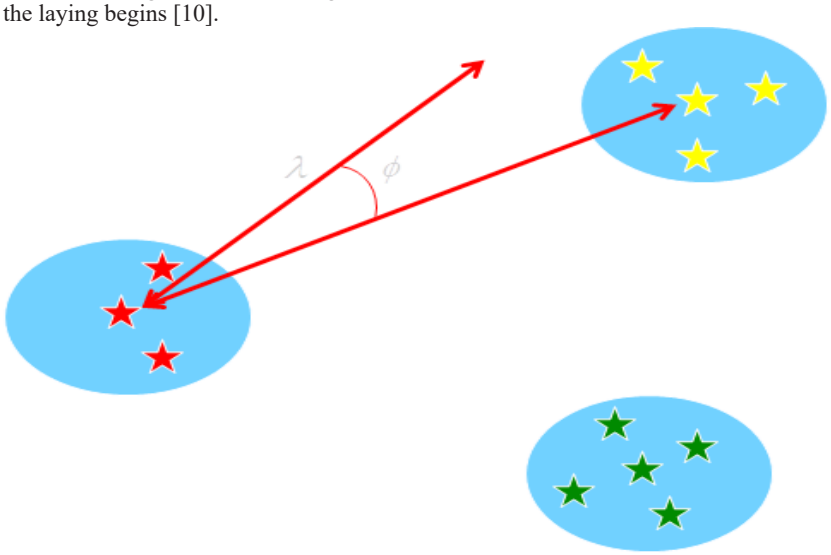

Fig. 8. Immigration of a sample cuckoo toward goal habitat.[10]

RESULTS

The fitness function has been considered as a function of B/H ratio and we minimize the cost function using COA algorithm.

COA procedure due to rapid convergence, Global progress is superior to GA and PSO standard versions[10]. In another research, MCOA was also introduced. The gradual reduction of parameters defined by ELR (4) was the main purpose of MCOA. MCOA method is used to optimize engineering issues such as pressure vessel design and welding beam design. The results show the superiority of the MCOA method compared with the COA method [11].

To investigate the effects of dam height (H) and base width (W) by finite element method, several analyzes in finite element model have been performed[12] (See Table 2) Fig.9. B and H design variables in this paper.Changing B and H lead to displacement of the crest dam.Therefore, we define a cost function for displacement in terms of B and H. For example, a cost function can be defined as follows:

$$Z=aY_1^4+bY_1^3+cY_1^2+dY_1+e \quad (6)$$

Where, Y_1 is the B/H ratio and a,b,c,d,e are the coefficient , which is obtained from the analysis of the plaxis data.This ratio is optimally find using COA algorithm . The results of the lateral surface model analysis should be selected less than twice the height of the dam in the finite element model.

In this work an energy fitness function has been defined so that horizontal displacement time history at the dam crest in the finite element model on the earthquake response be minimized.

In this experiment, the following COA parameters are used:

1)Number of initial population = 10, 2) Minimum number of eggs for each cuckoo = 5, 3) Maximum number of eggs for each cuckoo = 10, 4) Maximum iterations of the Cuckoo algorithm = 50, 5) Number of clusters that we want to make = 3, 6) Lambda variable in MCOA =2, 7) Maximum number of cuckoos that can live at the same time = 80, 8) Control parameter of egg laying reduced from 200 to 5, 9) Population variance that cuts the optimization =1e-13. B and H parameters change between 50-200 and 30-90, respectively. The COA algorithm were implemented using MATLAB from Math Works. In this experiment, by using the COA algorithm the B/H ratio should be equal to 1.81.

In Figure 10, the optimal function shows the proposed cost.

Table 2. Desired Dam Heights And Foundation Width Lateral Extents(B)

Model number	1	2	3	4	5	6	7	8	9
H* (m)	30			60			90		
B* (m)	50	100	200	50	100	200	50	100	200
W* (m)	303	403	603	498	598	798	669	769	969

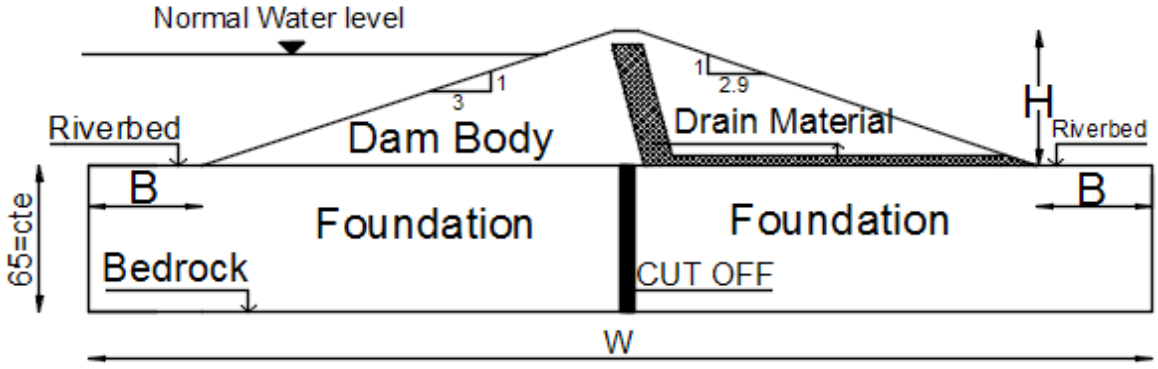

Fig 9. Section Dam Heights And Foundation Width Lateral Extents

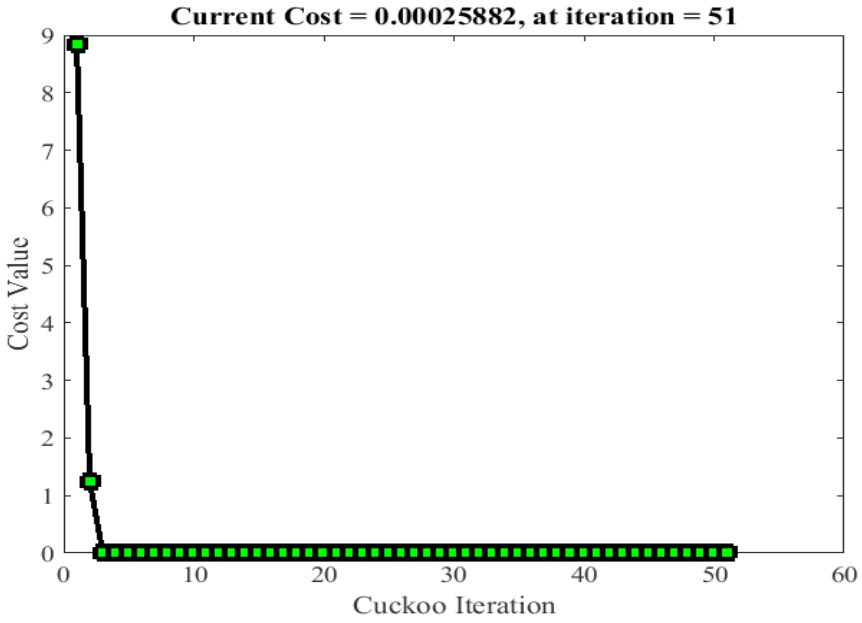

Fig 10. The cost functions of the proposed method after 50 iteration

CONCLUSION

In this study, dynamic analysis of Homogeneous earth dam (Iran) considering dam-foundation coupled model with various widths of foundation (50,100,200) meters and , heights of dam (30,60,90) meters under horizontal component of Manjil earthquake has been performed using the Plaxis program[13].In the previous work, B/H ratio has been adjusted experimentally. But, in this research it has been found optimally using COA algorithm. Several methods have been performed and the results pso and cuckoo indicate good performance of these methods.

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