Application of Adaptive Genetic Algorithm in Inversion Analysis of Permeability Coefficients

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Abstract

Permeability coefficients of dam foundation are inversed on the base of real water heads. Otherwise, simple genetic algorithm has the disadvantages in determining the optimal probability values of the crossover and mutation, computation quantity is great and premature phenomena easily appears. Adaptive genetic algorithm is proposed to overcome the disadvantages which simple genetic algorithm has. At same time, adaptive genetic algorithm is used to identify the permeability coefficients of Er Tan dam foundation. The result shows that the method is effective in improving the computational convergence and overcoming the premature phenomena. So adaptive genetic algorithm is efficient and feasible in back analysis for permeability coefficients of dam.

1. Introduction

The rock itself is a very complex and uncertain system as a kind of natural geological body, so its physical parameters, constitutive models, computation boundary conditions are obtained difficultly. Thus it is nearly impossible to obtain the relative parameters by the traditional analysis methods[1~3]. With the development of computer technology and rock mechanics, the new methods are provided to get relative parameters with the inverse analysis and many achievements are obtained in geotechnical engineering[4~6].However,traditional optimization methods as the core of inverse analysis whose the results depend on initial values of parameters, premature phenomena easily appear, and stability is poor in calculation process. Especially when the variables increase, the computation efficiency greatly reduces, even the result is non-convergent. At present, Genetic Algorithm is used widely in the inverse analysis due to unique properties of its own[7]. Genetic algorithm is gradually regarded by the engineering field and is the new way for solving the seepage inverse analysis[8] .

2. Adaptive genetic algorithms

Genetic Algorithm(GA)is characterized by its current effectiveness, strong robustness, and simple implementation. It has the advantage of not being restrained by certain restrictive factors of searching space. Due to the advantages mentioned above, it has been applied successfully to many fields such as machine design, engineering optimization, economy forest, and so forth. It is very critical to confirm the

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crossover rate(P_c) and mutation rate(P_m) because they affect the result and the convergence of Genetic Algorithm. However, it is also very difficult to identify P_c and P_m in Simple Genetic Algorithm(SGA). The reason is simple. When P_c is too big, the new individuals are produced more faster, the inheritable model will be destructed more easily and the individual that possesses high adaptability will be destroyed quickly. Also, if P_c is too small, the searching process will become slow, even stagnated. If the mutation rate is too small, the new individual is not easy to produce. if it is too large, Genetic Algorithm becomes the completely random searching. Therefore, for different optimized problem, it is hard to verify the value of P_c and P_m. In Adaptive Genetic Algorithm[9] (AGA), P_c and P_m can auto-change with adaptability. When each individual adaptability in the population size is hardly consistent, then increasing the value of P_c and P_m. If the group adaptability rather disperse, then reducing the value of P_c and P_m. Meanwhile, the individua adaptability is higher than the group's average adaptability, corresponds the lower value of P_c and P_m, then the individual enters the next generation directly. And the individual, whose adaptability is lower than the group's average adaptability, corresponds the higher value of P_c and P_m, so that it can be washed out. So AGA can keep the convergence of GA while it keeps the diversity of individual.

3. Inverse analysis model of Seepage Coefficients

On the base of the error of the measuring and computation hydraulic head of Measuring points in the seepage field, the objective function $E(k_i)$ is built, The mathematical model is described as follows:

$$E(k_i) = \sqrt{\sum_{i=1}^{n} [\frac{h_i - h'_i}{h'_i}]^2}$$

Where, h_i is the computation hydraulic head of No. i point, h'_i is the real head of No. i point, n is the total numbers of measuring points, k_i is the seepage coefficient. The objective function using the relative value of the real hydraulic head can avoid some problems caused by different dimensions in the computation process. In addition, it is easy to judge the convergence of the genetic algorithm.

4. The inverse analysis program of Adaptive Genetic Algorithm

This algorithm can be described as follows:

(1) The first step of AGA is coding the permeability coefficients k_x, k_y and k_z as a binary string.

(2) Generate randomly n group of parameters at their given range. Each individual represents an initial solution.

(3) Input a set of parameters to the model obtained above to calculate the objective function $E(k_i)$ at the monitoring points.

(4) Evaluate the fitness of the current individuals. If all individuals are evaluated, then go to Step5.

Otherwise, go to Step 3.

(5) If the given evolutionary generation is reached, or the best individuals (the parameter to be back recognized) are obtained, then the evolutionary process ends. Otherwise, go to Step 6.

(6) Select randomly two individuals $i1$ and $i2$ from the parent generation. Carry out the crossover operation on the individuals $i1$ and $i2$ to generate a new chromosome. The new chromosome will pass on a single mutation and at probabilities of P_m to generate a new parameter set.

(7) Repeat Step6 until all n new individuals are generated. They are used as offspring.

(8) Replace randomly an individual in the offspring generation using the best parent's individual.

(9) Take the offspring as parent and go to step3.

(10) Output the best individuals and the optimal objective function value

5. Inverse analysis of seepage coefficients for the Er Tan dam

5.1. The project introduction

The Er Tan hydropower station is on Ya Long river. The Er Tan hydropower station locates the high mountain and steep gorge area. The slope gradient of it's banks is very steep. The valley is almost symmetric V-type valley. The Er Tan dam is the double curvature parabola arch dam. It's foundation is built on the orthoclase and basalt rock. The height of dam is 240m, and the flood discharge is 16500 m^3/s.

5.2. Building and calculating the model

The dam is divided into 24 parts. According to observation results, the No.12 dam section is selected as the computation area (as Fig.1). The physical model of the No.12 dam section is expressed as follows: getting the one times height of dam for the upstream, getting the one times height of dam for the downstream, getting the one times height of dam for the foundation, and the width of the No.12 dam section is 25m. The model of No.12 dam section is expressed as Fig.2. Based on the different seepage parameters, the dam is divided into two parts: the body of dam and the foundation. The range of element meshing is from the free surface of seepage to the foundation 240m depth. After divided, the No.12 dam section has 1200 eight-node hexahedron elements and 2904 nodes.

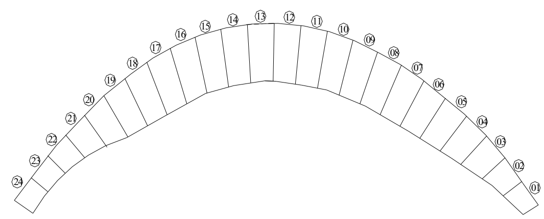

Fig 1 The distraction of dam

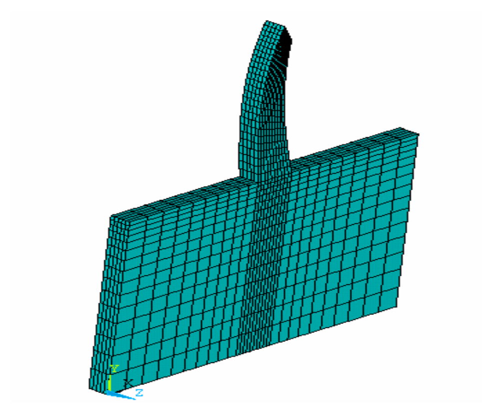

Fig 2 3-D FEM model of NO.12 dam section

In the 3-D model, the origin of coordinates is A point, the upstream boundary hydraulic head is 235m, the downstream boundary head is 50m, and the boundary flux is 0 cm^3/s. The seepage coefficients k_x, k_y and k_z are the inverse parameters. The upper limit of seepage coefficients k_x^1, k_y^1 and k_z^1 is 1.0×10-5m/s and the lower limit of seepage coefficients k_x^2, k_y^2 and k_z^2 is 1.0×10-10m/s. The coordinate and hydraulic head of the measuring points is expressed as table 1.

Table 1 The coordinate and hydraulic head of the measuring points

Measuring Points	the coordinate values			real hydraulic heads
	X	Y	Z	
1	5.0	270.63	283.0	242.16
2	10.0	243.72	241.76	291.71
3	15.0	264.82	282.0	293.23
4	15.0	231.99	474.98	474.97
5	20.0	243.76	460.33	460.35
6	5.0	232.37	467.62	467.57

Table 2 The error of the measuring and computation of hydraulic head

hydraulic heads	Measuring Points					
	1	2	3	4	5	6
real hydraulic heads	242.16	291.71	293.23	474.97	460.35	467.57
computation hydraulic heads	238.13	294.82	290.51	490.91	462. 75	471.13

Table 3 The error Value of different generations

parameter	generations		
	1st generation	50th generation	100th generation
K_x (m/s)	9.0×10^{-6}	6.01×10^{-8}	6.01×10^{-8}
K_y (m/s)	6.89×10^{-6}	3.23×10^{-8}	3.23×10^{-8}
K_z (m/s)	5.36×10^{-6}	5.42×10^{-8}	5.25×10^{-8}
objective function	0.06531	0.0186	0.0186

The 3-D back analysis program is used to analyze the seepage field. After calculated, The objective function and seepage coefficients k_x, k_y and k_z are obtained and The results is expressed as table 2 and 3. From the table 2, the hydraulic head errors of 6 points are small. The largest error is 4th point and the error of the measuring and computation of hydraulic head is 15.94m. However, the smallest error is 5th point and the error is 2.4m. Generally, the error is very small. From the table 3, the objective function value converges at 0.0186 from 50th generation. Meanwhile, k_x, k_y and k_z converge at 6.01×10^{-8}, 3.23×10^{-8} and 5.25×10^{-8} respectively. However, on the base of the measuring dates, the real seepage coefficient is between 5.0×10^{-6} m/s and 1.0×10^{-8} m/s. It shows the computation values seepage coefficients are slightly smaller than the real values. The reason is that the foundation grouting curtain is considered. Consequently, the computation values are slightly smaller than the real values.

6. Conclusions and discussions

It can be shown from the above analysis that adaptive genetic algorithm is effective in improving the convergence, overcoming the premature phenomena and the disadvantage seriously depending on initial values of simple genetic algorithm. Furthermore, the computation efficiency and convergence of adaptive genetic algorithm is very high. Based on the inverse analysis of Er Tan arch dam, adaptive genetic algorithm is efficient and feasible in the back analysis for seepage coefficients of dam foundation.

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