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## Research on Optimal Design of Foundation Pit Anchor Support based on Improved Particle Swarm Optimization

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# Research on Optimal Design of Foundation Pit Anchor Support based on Improved Particle Swarm Optimization

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**Abstract.** The engineering technology of deep foundation pit support is complex and comprehensive, and it is necessary to consider the relationship between safety and engineering cost, and the optimal design of foundation pit support is especially important. Anchor support is a common support way for deep foundation pit support, in allusion to the shortcomings of particle swarm optimization; this paper adopts genetic algorithm, step length acceleration method and improved particle swarm optimization to carry out optimal design for foundation pit anchor support. The optimization results show that the combination with genetic algorithm improves the diversity of particle populations, the particle swarm optimization combined with the step length acceleration method has faster convergence performance, and the mathematical model of anchor supporting structure design is established. Through the case study of the foundation pit support of the super-high-rise building with frame shear wall structure, it was found that the engineering cost of the improved anchor support scheme after the improved particle swarm optimization is lower. The research in this paper provides a mathematical model for foundation anchor support.

## 1. Introduction

With the gradual increase of depth and scale of the underground excavation space, the excavation depth of the foundation pit is also from a few meters to a dozen meters, or even tens of meter, the deep foundation pits like mushrooms after rain, which appear in succession with the construction of high-rise and super high-rise buildings, due to various reasons, foundation pit accidents occurred occasionally (Rong-Guei & Pei-Hsuan, 2018). Foundation pit support design is very important to the safety of foundation pit engineering, the theoretical method, support scheme and structural design parameters of foundation pit design all have non-uniqueness, it is necessary to carry out optimal design of foundation pit support scheme (Mondal et Al., 2016). At present, the commonly used foundation pit support ways include steel sheet pile, reinforced concrete pile, soil nailing wall, diaphragm wall, etc, anchor support is a commonly used reinforcement support way in deep foundation pit engineering in recent years, and



has low cost, good support effect, simple operation is simple, flexible use, and less construction are headroom (Gumaida & Luo, 2018).

The optimal design of anchor support is divided into three aspects: system optimization, design calculation optimization and dynamic inversion analysis optimization. The commonly used optimization methods are genetic algorithm, step length acceleration method, simplex algorithm and particle swarm algorithm (Wendeborg & Schindelbauer, 2014). The particle swarm optimization algorithm shows stronger superiority in comparison with other algorithms, which can be described by mathematical model (Guangjie et al., 2014). Based on the improved particle swarm optimization, mathematical description is carried out for optimization problems of detail structure of anchor support in this paper, and the mathematical model of the optimal design of the support structure type detail is established.

## 2. Improvement of Particle Swarm Optimization in Foundation Pit Anchor Support Optimization

The particle swarm optimization belongs to global optimization algorithm, but it does not follow the global convergence, the anchor support optimization problems have many design variables, if it does not converge or the convergence speed is slow, the optimal support scheme cannot be obtained. The optimization algorithm parameters is set, the speed and position of the initial population are determined, as shown in formula 1 and 2, the current positions of each particle are stored in the pbest of each particle, and the optimal individual is stored in gbest, according to formula 3 and 4, the flight speed and position of each particle are updated, the genetic operator operation is carried out, and local search is carried out according to step length acceleration method.

Speed of initialized population:

$$v_i(0)=(v_{i1}(0), v_{i2}(0), \dots, v_{id}(0)) \quad (1)$$

Position of initialized population:

$$X_i(0)=(X_{i1}(0), X_{i2}(0), \dots, X_{id}(0)) \quad (2)$$

$$v_{ij}(k+1)=w*v_{ij}(k)+c_1*r_1*(p_{ij}-X_{ij}(k))+c_2*r_2*(p_{gj}-X_{ij}(k)) \quad (3)$$

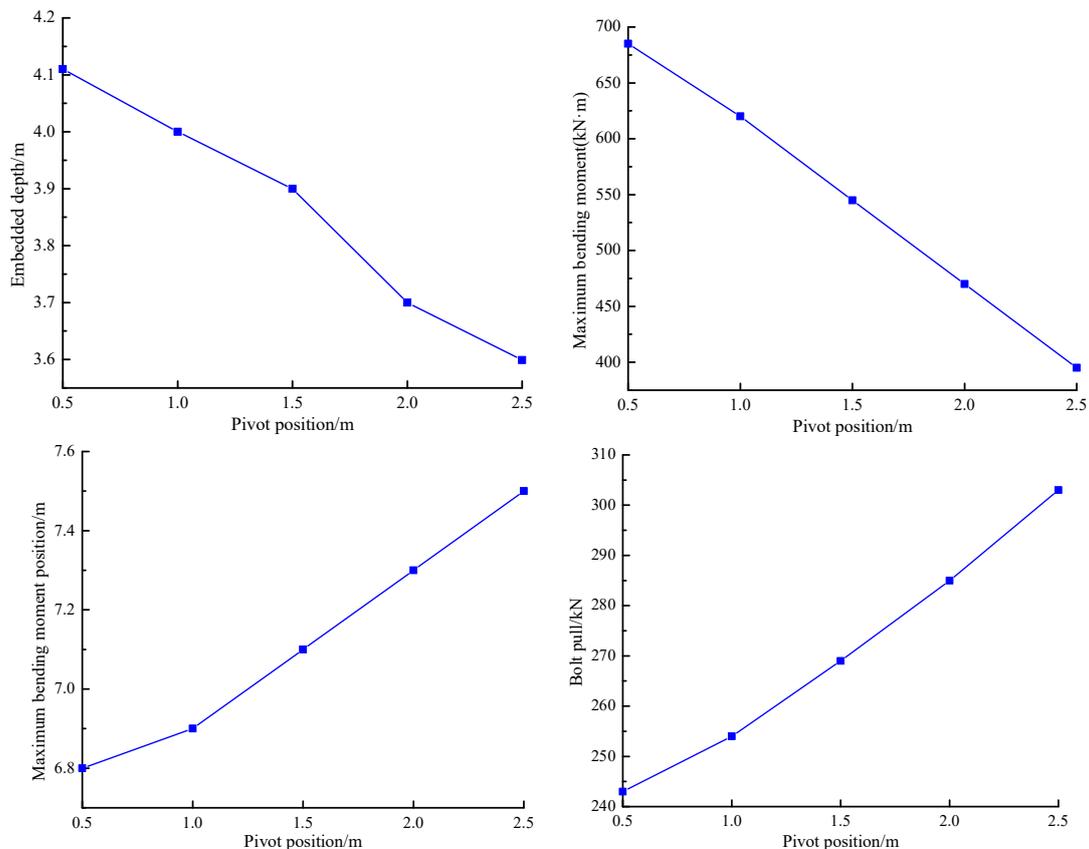
$$X_{ij}(k+1)=X_{ij}(k)+v_{ij}(k+1) \quad (4)$$

## 3. Research on Mathematical Model of Optimal Design of Anchor Supporting Structure

The optimized mathematical models of the anchor supporting structure must maximally pursue the optimization of the objective function, the anchor support has many design variables, and many optimization variables are selected (Suhadolnik et al., 2009). The optimization variables selected by some scholars include pile diameter and pile center distance, and some scholars have carried out optimization of embedded depth of support pile and the optimization of anchor pivot point position (Ou & He, 2013). Fig.1 shows the influence of the position of anchor on the calculation results, as the position of the pivot point moves down, the embedded depth and the maximum bending moment decrease linearly, the position of the maximum bending moment is farther and farther from the top of the pile, the tensile stress increases accordingly, so adjusting the position of the anchor point can get a good optimization effect. The mathematical models of anchor support are optimized by the engineering cost as the optimization objective function, the cost reach optimal by optimizing the design parameters of the anchor; the optimization objective function of the pivot point anchor support structure is shown in formula 4:

$$f(dp, S, h_d, h_T) = \frac{L}{S} \left( \frac{\pi}{4} \cdot d_a^2 \cdot l_a \cdot C_a + \frac{\pi}{4} d_p^2 \cdot (H+h_d) \cdot C_c + A_S (H+h_d) \cdot C_S \right) \quad (5)$$

In the formula: L represents perimeter of deep foundation pit, S represents center distance of pile,  $d_a$  represents diameter of the anchor,  $h_T$  represents position of pivot point of anchor, and  $C_a$  represents the cost of the anchor /m<sup>3</sup>.



**Fig. 1** The influence of the position of the anchor point on the calculation result

## 4. Example Analyses

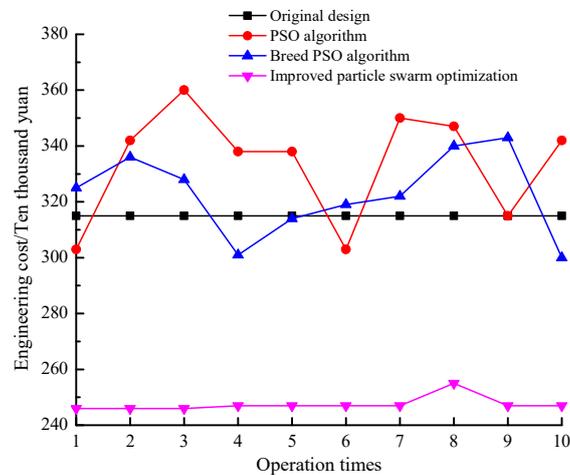
### 4.1. Foundation pit support scheme

The foundation pit support of super high-rise building with frame-shear wall structure is selected as an example in this paper, the average excavation depth is 8.6m, the stability condition of geological structure is good, and the importance level of foundation pit support is second level. The foundation pit support selects bored double-row pile and pre-stress anchor support, the diameter of the anchor is 200mm, the pre-stress anchor adopts 1860 grade steel strand (strength is 1860N/mm<sup>2</sup>), open grouting all adopt cement paste, the grouting strength is 30 MPa, the pre-stress tension of the anchor is carried out when the strength reaches 21 MPa. The length of the anchor is 41m, the inclination angle of the anchor is 35°, the elevation of the anchor head is 2.1m, and the design value of the axial tension is 680kN.

### 4.2. Optimal design of foundation pit support structure for improved particle swarm optimization

The optimization calculation is carried out for the foundation pit anchor support structure based on the improved particle swarm optimization in this paper, and compares with the commonly used PSO algorithm and the Breed PSO algorithm, the engineering cost as the evaluation condition. The support position of the anchor is optimized by comparing and the structure of the improved particle swarm optimization, and the maximum bending moment of the anchor is reduced due to the downward movement of the support position, the algorithm is run 10 times by Matlab calculation program, Figure 2 is a relationship curve diagram between the operation number of each algorithm and the optimization results, it can be clearly seen that the anchor support scheme cost of original design is 3.15 million Yuan, after the optimization of improved particle swarm optimization, the cost is 2.49 million Yuan, the support project saved 66 thousand Yuan in comparison with original design, the improved particle

swarm optimization has lower engineering cost in comparison with the PSO algorithm and the Breed PSO algorithm.



**Fig. 2** The relationship between the number of operation times of each algorithm and the optimization result

## 5. Conclusion

The mathematical description is carried out for the detailed structure optimization problems of the anchor support based on the improved particle swarm optimization in this paper, and the mathematical model of the detailed optimal design of the support structure type is established, the specific conclusions are as follows:

(1) With the downward movement of pivot point position of the anchor, the embedded depth and the maximum bending moment decrease linearly, the position of the maximum bending moment is farther and farther from the top of the pile, and the tensile stress of the anchor increases accordingly, therefore, adjusting the position of the pivot point of the anchor can achieve a good optimization effect.

(2) Example analysis found that the engineering cost of the foundation pit anchor support scheme after improved particle swarm optimization is lower.

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