ISSN: 1813-4890

Numerical simulation of bias pressure in reinforced concrete columns with iron tailings sand

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Abstract

As the main structural form of modern building engineering, the study of mechanical properties of reinforced concrete structure is very important to ensure the safety and reliability of the structure. In this paper, based on numerical simulation method, the mechanical response of reinforced concrete bull leg columns with different strength grades of iron tailings under eccentric pressure loads is analyzed. By establishing abaqus finite element model, the influence of different strength grades of iron tailings concrete on the bearing capacity and deformation performance of bullcolumn was studied. The research results will help to expand the application range of iron tailings in engineering practice and promote the application of sustainable building materials.

Keywords

Iron tail sand concrete, Bias bearing capacity, Numerical simulation.

1. Introduction

With the continuous development of human society, the need for more sustainable materials and structural design in construction engineering is becoming more and more urgent. Iron tailings, as a kind of waste containing rich iron oxide, has been widely concerned because of its production in the process of mine tailings treatment. Iron tailings usually contain a certain amount of useful metals and minerals, making the availability of iron tailings poor. The best way to solve the problem of iron tailings is to develop large-scale utilization technology and adopt new technology to promote the consumption of large amounts of waste. However, it is still a problem worth exploring how to apply iron tail ore effectively and give full play to its potential. Reinforced concrete structure, as the main form of building structure, needs to have strong bearing capacity and deformation performance under the action of resisting external load and self-weight load. However, the traditional concrete materials have problems such as resource waste and environmental impact. Therefore, research on the application of new materials, such as the incorporation of iron tailings into reinforced concrete, can not only effectively reduce the environmental impact, but also optimize the performance of the structure.

The purpose of this paper is to explore the application potential of iron tail sand in reinforced concrete column by numerical simulation method. By constructing a detailed finite element model, we study the behavior of the bull leg column under eccentric pressure load of iron tailings sand and ordinary concrete with different strength grades. This research is expected to provide a new perspective on the application of iron tailings in engineering practice and contribute to the development of sustainable building materials.

2. Research method

2.1. Material model

The calculation model is based on the concrete plastic damage model in ABAQUS, which uses isotropic elastic damage combined with isotropic tensile and compressive plasticity to replace the inelastic behavior of concrete. Among them, the inelastic strain and damage factors can be calculated according to the stress-strain curve of concrete provided in Appendix C of Code for Design of Concrete Structures (GB50010-2010) and the principle of energy equivalence. In the finite element simulation, the nonlinear behavior of concrete and reinforcement is considered. The Drucker-Prager constitutive model was adopted for concrete in this time, and the elastoplastic model was adopted for rebar to simulate its deformation and failure process under load. Ma Jiangbo gave the basic parameter setting of concrete. The basic parameters of concrete were partially modified according to its data processing, as shown in Table 1

Table 1 Basic parameters of concrete

Expansion Angle	Poisson's ratio	Eccentricity	fb0/fc0	K	Coefficient of viscosity
36	0.2	0.1	1.16	0.67	0.005

2.2. Calculation of normal section bearing capacity of compression member

The stress-strain relationship of iron tailings concrete is adopted by Kang Hongzhen:

$$y=\begin{cases}\alpha_a x+(3-2\alpha_a)x^2+(\alpha_a-2)x^3 & x\le 1\\ \dfrac{x}{\alpha_d(x-1)^2+x} & x>1\end{cases}$$

Annotation: $x=\varepsilon/\varepsilon_p, y=\sigma/\sigma_p, f$ Compressive strength of concrete, α_a Is the shape parameter of the rising section, α_d Is the shape parameter of the descending section.

When the strength grade of iron tailings concrete is less than C40, the above relation is adopted. When the strength grade of iron tailings concrete is greater than or equal to C40, the shape parameter of the descending section α_d should be modified to: $\alpha_d = 0.785 f_c^{0.195} - 0.905$

3. Geometric model

3.1. Build finite element model

A three-dimensional finite element model is established to simulate the geometric shape and size of the bull leg column. The deformation of the structure under eccentric load is considered. The shape of the part is shown in Figure 1. The size of the part is 250mm×250mm×3000mm. The protruding part of the bull leg is 150mm and the height of the bull leg is 300mm. The specific dimensions are shown in Figure 2

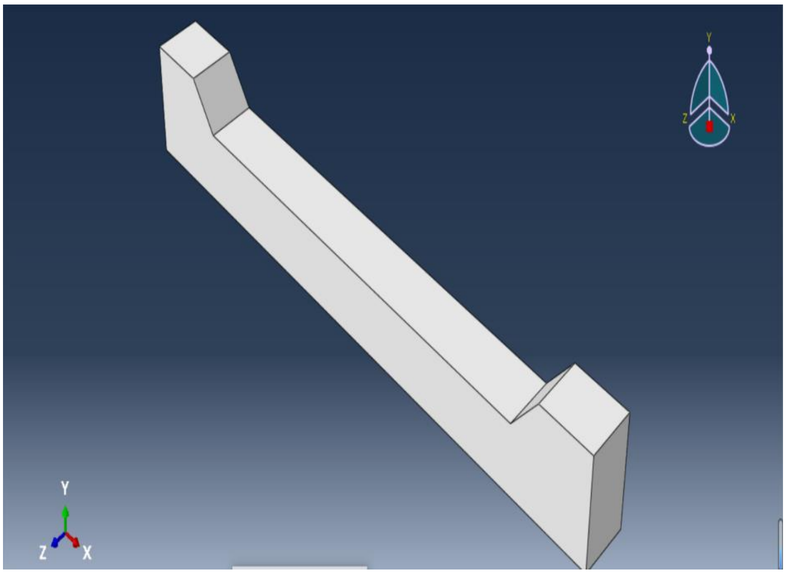

Figure1. Three-dimensional finite element model of bull leg colum

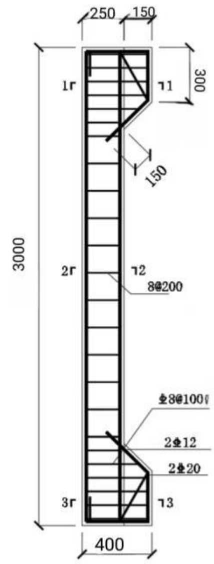

Figure2. Shank size

3.2. Boundary conditions and loads

In the simulation, vertical loads and eccentric loads are applied to consider the forces in the actual project. The load is applied step by step to analyze the bearing capacity and deformation performance of the structure. Step-1 is used to control the stress of the specimen during the application of vertical load. Due to the displacement of the specimen under the action of eccentric force, the geometric nonlinear parameter in the analysis step was set to On(ON). The analysis Step time in step-1 is set as 1. The simulation will convert the eccentric force into surface force according to the actual situation of the test, and apply a constant uniform load to the top of the column to prevent the top surface of the specimen from being damaged by the concentrated load. The bottom of the column is completely hinged, and the effect diagram is shown in Figure 3

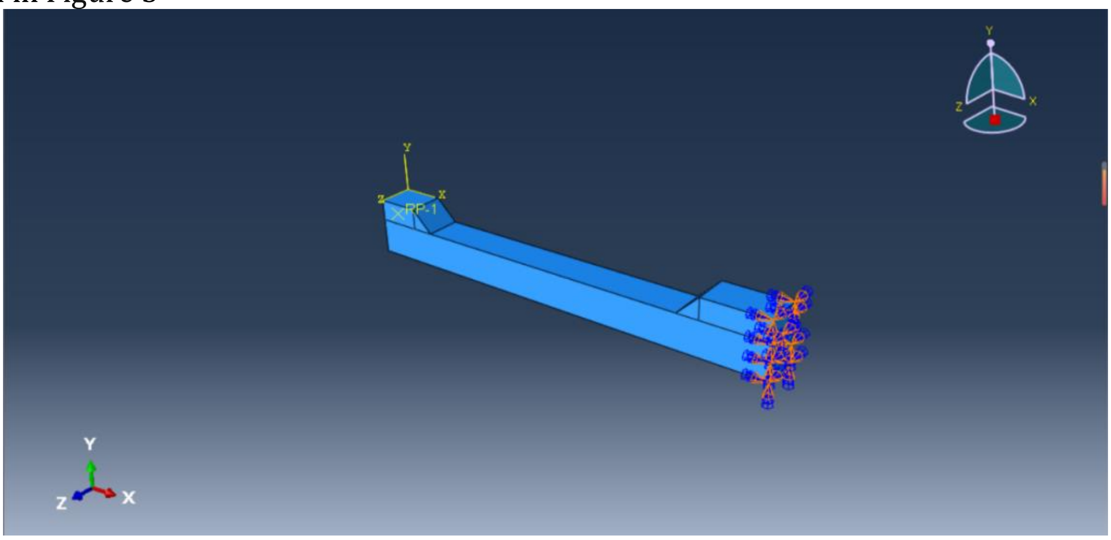

Figure3. Diagram of applying pressure and fixing articulation

3.3. Meshing

In Abaqus, meshing is a key step, dividing a continuous structure into discrete units for numerical computation. Good meshing can affect the accuracy and stability of the analysis results. Through the irregular division, in order to standardize the mesh division aesthetic. The graphical interface provided by Abaqus is applied for grid partitioning and model setting. The grid calculation diagram is shown in Figure 4

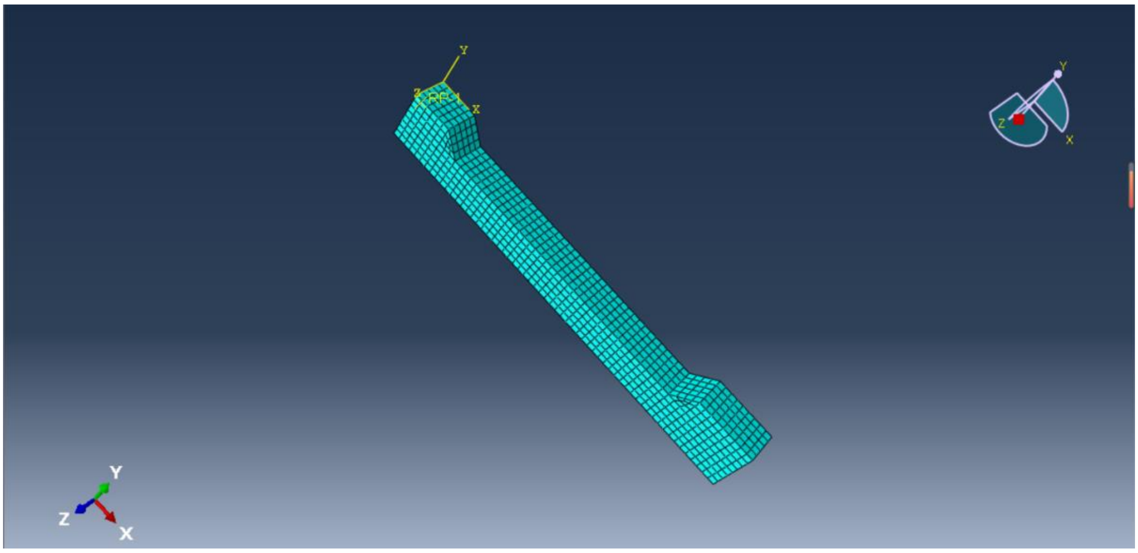

Figure3. Calculation model

4. Numerical simulation results and discussion

Through numerical simulation, the mechanical performance curves of the column under different strength levels are obtained. The bearing capacity, deformation and failure mode of the column are analyzed by comparing with the ordinary concrete column of the same grade. The results show that the reinforced concrete bullock column has good bearing capacity, and the deformation increases gradually after the bearing capacity reaches its peak. A numerical simulation model was established by ABAQUS to obtain the simulated compressive capacity, as shown in Table 2.

Table 2 Simulated compressive capacity

Specimen number	Grade of concrete	Eccentricity /mm	Ultimate bearing capacity /KN
NZ-1	WCS30	125	831
NZ-2	WCS40	125	928
NZ-3	WCS50	125	989
NZ-4	PC30	125	800
NZ-5	PC40	125	907
NZ-6	PC50	125	963

According to the comparison between the simulated compressive capacity of reinforced concrete bull leg column of tailings sand and that of ordinary reinforced concrete bull leg column, a line chart is drawn, as shown in Figure 4 and Figure 5.

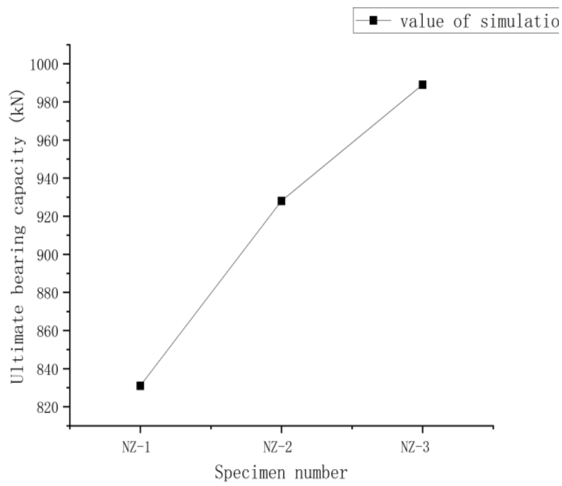

Figure4. Iron tailings concrete

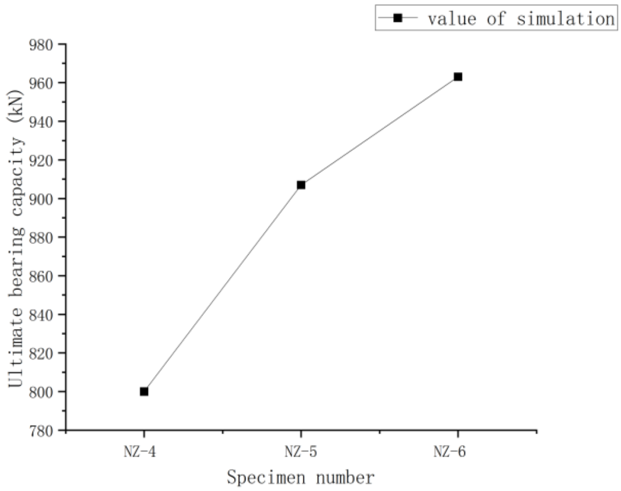

Figure5. Ordinary reinforced concrete

According to the broken line and data shown in the figure, under the same strength grade, iron tail sand concrete has a higher ultimate bearing capacity than ordinary concrete. In the case of the same material and different strength grades, the higher the strength grade, the greater the bearing capacity. The curve trend is roughly the same, and the numerical difference is within a reasonable range, and the laboratory experiment results are often higher than the finite element simulation results. The test value is larger than the simulated value because the compressive strength of concrete is 360Mpa in the calculation, and the numerical value is more conservative, while the real bearing capacity remains more, so it is larger than the simulated value, but still within a reasonable range [10]. It provides some theoretical basis for promoting the application of iron tailings in engineering practice. This means that in engineering structures requiring higher performance, the use of high-strength concrete can be considered to improve the safety and reliability of the structure.

5. Numerical simulation

(1) The iron tail sand reinforced concrete column still has higher bearing capacity than the ordinary reinforced concrete column. For some leg column application scenarios, iron tail ore can be used to meet the construction requirements.

(2) For the bull leg column of the same material, the strength level is increased, and the corresponding bearing capacity is also increased. It is roughly the same as the common concrete bull-leg column.

(3) In this paper, by means of numerical simulation, the mechanical behavior of reinforced concrete bull leg column under eccentric load is studied. The results show that iron tailings can be used as a potential alternative material in reinforced concrete structures. In practical engineering, it is necessary to determine the appropriate strength grade according to the structural design requirements to ensure the safety and reliability of the structure.

(4) It should be noted that the cost of high-strength concrete is usually higher, so performance and economy need to be considered comprehensively in engineering design.

References

[1] Meng Yue-Hui, Ni Wen, ZHANG Yu-Yan. Development status and prospect of comprehensive utilization of tailings in China [J]. China Mine Engineering. 2010. 39(5):4-9.

[2] Ma Zhen. Experimental Study on Shear performance of iron tail sand concrete [D]. Tangshan: North China University of Science and Technology,2018.

[3] Code for design of concrete structure: GB50010-2010 [S]. Beijing: China Architecture and Construction Press, 2010.

[4] Jiang-bo ma. The tail of iron ore, finite element analysis of seismic performance of reinforced concrete columns [D]. North China university of technology, 2022. The DOI: 10.27108.

[5] Kang Hongzhen, Zhang Kai, Ma Weihua, et al. Experimental study on full stress-strain curve of iron tailings concrete under axial compression [J]. Journal of Building Structures, 2015,36 (S2):373-378..

[6] Kang Hongzhen, Zhang Kai, Ma Weihua, et al. Experimental study on full stress-strain curve of iron tailings concrete under axial Compression [J]. ConstructionJournal of Structural Engineering, 2015, 36(S2):373-378.

[7] Wang Dongwei. Study on Structural Mechanical properties of iron tail sand concrete [D]. Tangshan: Hebei United University,2013.

[8] Zhang Ning. Research on deformation ability and horizontal displacement calculation of Reinforced concrete column [D]. Chang 'an University,2019.

[9] Zhang Longsheng. Experimental study on flexural stiffness and crack of simply supported iron tailings concrete beams [D]. Chengdu: Southwest Southwest Jiaotong University, 2015.