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Application of Nonlinear Finite Element Analysis of Concrete in Structural Engineering

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Abstract

This paper introduces the application of nonlinear finite element analysis, briefly summarizes the development history of nonlinear relations, summarizes the application of nonlinear analysis to the mechanical properties analysis of concrete-filled steel tube members and beam and column joints under different parameters, the nonlinear analysis of concrete-filled steel tube members and its temperature field analysis under high temperature, providing reference for the future nonlinear research of concrete-filled steel tube members.

Keywords

Concrete; Nonlinearity; Nonlinear Finite Element Analysis; Structural Engineering.

1. Introduction

Nonlinearity is one of the most obvious characteristics of concrete structure. However, in order to simplify the analysis in the previous learning process, concrete is regarded as isotropic material for learning and analysis. Concrete member is composed of steel bar and concrete. Concrete is made of cementing agent, fine aggregate, coarse aggregate, water and various admixtures, admixtures mixed and hardened. Steel in the production process and hot rolling, cold rolling and so on. Therefore, in the process of steel bar production and concrete forming, it will become a nonlinear component due to various factors. In order to make the calculation analysis more realistic, nonlinear analysis is extremely important. Ngo and SCORDELIS [1] applied the finite element method to the nonlinear analysis of reinforced concrete. NGO [2] proposed to use contact elements without volume to simulate the slip between concrete and steel. NILSON [3] makes use of the nonlinear characteristics of concrete and reinforcement, and adopts load increment method to carry out nonlinear analysis of reinforced concrete structure. Over the years, nonlinear analysis has been widely used in practical engineering through many scholars' research and improvement.

2. Nonlinear Analysis of Mechanical Properties of Concrete Members

2.1 Concrete-filled Steel Tube Column

CHA X X et al. [4] carried out a nonlinear analysis on the influence of the initial stress on the compressive performance, axial bearing capacity and flexural performance of concrete-filled steel tube (CFST) with initial stress, and finally gave the strength and stability checking formula of CFST with initial stress. Yu Y et al. [5] established a finite element model of concrete-filled square steel tube column based on the subelastic orthotropic theory of concrete and Von Mises elastoplastic model of steel, and carried out nonlinear analysis on it under three-dimensional conditions, and found that the model established with this method had less input data, stable calculation, simple and efficient. It provides an effective means to study the internal mechanism of concrete-filled square steel tube

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structure. Guo Q Q et al. [6] carried out nonlinear analysis on the composite columns of concrete-filled steel tubes, adopted Gaussian integral method for programming, and adopted elastic-plastic relation curve (two-broken line relation) for the constitutive relation of steel (steel bar and steel pipe). The constitutive relation of concrete outside pipe adopts the piecewise equation proposed by GUO Zhenhai. A program for calculating section stiffness matrix of concrete-filled steel tube composite column is developed. Arc length method is used to control iteration to analyze the whole process. The results are in good agreement with the experimental results and N-M correlation curves of the composite column are obtained.

LI X P et al. [7] carried out finite element simulation of T and L steel tube concrete columns. Saenz formula was used in the rising section of concrete, and double-broken line form was used in the falling section to analyze the load-displacement and load-strain relations under reciprocating loads. However, when this model is used to study the mechanical properties of different types of concrete-filled steel tubes, it is necessary to adjust the relevant parameters of concrete and carry out relevant tests for verification. LIU Q et al. [8] used ABAQUS software to establish a finite element model by changing the external concrete strength, steel pipe diameter, wall thickness, axial compression ratio, etc., and compared the bearing capacity changes of T-shaped concrete-filled steel tubular core column under different conditions, analyzed the bearing capacity changes under different factors, and found that the diameter of steel pipe and the internal concrete strength had a great influence on the bearing capacity. WANG W H et al. [9] used the software ABAQUS to establish the model of a composite short column with outer square and inner circle for nonlinear finite element analysis under axial compression, obtained the ultimate bearing capacity of the composite column with outer square and inner circle and the corresponding load-deformation curve, and analyzed the stress characteristics of the composite short column under different parameters. Through experiments and simulations, it is found that the bearing capacity of composite column increases first with the increase of steel pipe diameter, but the bearing capacity does not increase obviously after the diameter reaches a certain degree. MA H et al. [10], in order to further solve the performance of recycled concrete composite members of square steel tubular section, established a model with ABAQUS to conduct numerical analysis under the condition of biased pressure, and compared the test results, found that the eccentricity and sleneness ratio had obvious adverse effects on the bearing capacity of recycled columns. Finally, based on the test, superposition principle and existing specifications, a practical calculation formula for the bearing capacity of biased column is proposed which can meet the requirements of engineering calculation.

2.2 Beam-column Joints

WANG S et al. [11] adopted Zhu Bolong et al. 's Nonlinear Analysis of Reinforced Concrete, Y. HIGASHIBATA' s steel constitutive relation and HAN L H 's constrained concrete constitutive model to conduct nonlinear finite element analysis of concrete-filled steel tube beam-column joints with ANSYS, and compared the seismic performance of joints of bolt welded joints and all-welded joints under simulated earthquake action. It is found that both methods have good seismic performance, but the performance of full-welded connection is better than that of bolt welded connection. NIE J G et al. [12] used ANSYS software to establish a square-rigid-tube concrete column model without considering the bond and slip of steel pipe and concrete by adopting the three-fold model of steel plate and the elastic-plastic constitutive model of incremental theory in ANSYS to carry out cyclic loading analysis of column joints. The effects of different coaxial-pressure ratio, width-thickness ratio and different concrete strength on the seismic performance of the joint were studied , and compared with the test structure. It is found that the axial compression ratio has a negative effect on the bearing capacity of the joint, while the width/thickness ratio has a positive effect on the bearing capacity of the joint. ZHANG J C et al. [13] build a test model of L-shaped concrete filled steel tubular column with nonlinear fiber beam and column elements in OPENSEES and conduct nonlinear analysis of its seismic performance. The test finds that the ratio of section width to thickness and the ratio of length to width have similar effects on the hysteresis curve of specimens, but have little effect on the load

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displacement curve. Axial compression ratio is inversely related to stiffness and horizontal ultimate bearing capacity.

3. Nonlinear Analysis of Concrete Member at High Temperature

XU L et al. [14] deduced the mathematical expression of surface temperature of concrete-filled steel tube column under fire condition, and calculated the temperature field of square section steel tube under high temperature with finite element method. Then, considering the effect of different protective layers and steel tube size on the temperature field, it provides a reference for the subsequent research on concrete-filled steel tube under fire. DING F X et al. [15] proposed a material thermo-mechanical coupling constitutive relationship that can reasonably reflect the constraint effect and deformation properties of concrete-filled steel tube columns under fire on the basis of a review of previous studies. They compiled the nonlinear finite element program NACFSTLF and proposed a solution method, which can reflect the stress characteristics of components under fire. A good condition is created for the calculation of bearing capacity and analysis of fire resistance performance. LIU Y et al. [16] used ANSYS, a finite element program, to consider the characteristics of thermal parameters of materials changing with temperature and calculate the temperature field distribution on the section of component during any temperature rise, which created conditions for the analysis of fire resistance of concrete-filled steel tube frame structure under local fire. Chen J B et al. [17] used ABAQUS software to carry out finite element analysis on concrete-filled steel tube columns to explore that the mortar protective layer has positive fire resistance and heat insulation effect on the internal structure, which can slow down the excessive heating of the internal steel bar, so as to ensure the bearing capacity of the member under fire.

4. Conclusion

With the gradual improvement of finite element analysis method and the popularity of finite element software, nonlinear finite element analysis is very common in reinforced concrete structural engineering. Using finite element analysis, modeling of structure, comparative analysis of dynamic characteristics of structure, deformation checking calculation of structure, numerical simulation of structural failure process and response analysis of structure under the action of earthquake are all the applications of finite element analysis in structural engineering. The application of nonlinear finite element analysis in structure greatly simplifies the calculation of concrete structure engineering, can save time cost and capital cost, and improve the accuracy of the test.

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