Discussion on Nonlinear Finite Element Analysis of Reinforced Concrete

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Abstract

From the nonlinear finite element analysis theory of reinforced concrete and its application in structural engineering, illustrating the nonlinear finite element analysis of reinforced concrete has become an indispensable part of structural analysis.

Keywords

Nonlinear; finite element analysis.

1. Introduction

Reinforced concrete is one of the most widely used structures in civil engineering. However, the mechanical properties of reinforced concrete, especially concrete, cannot be fully grasped. Because concrete is made of cement, water, sand, stone and various admixtures or admixtures, it is a building material with complex composition and various properties. For a long time, people used the linear elasticity theory to analyze the stress or internal force of reinforced concrete structures, and determined the bearing capacity, stiffness, and crack resistance of the members by the design method of the limit state. Obviously, the two are incompatible with each other. This design method is often based on empirical formulas on a large number of experimental data. Although these empirical formulas can reflect the inelastic properties of reinforced concrete members, they are also effective and simple for conventional design, but there are limitations in their use. There is also a lack of systematic theory. The shortcomings of this design method are:

(1) The design formulas provided by the specification often use model tests or analytical methods using elastic mechanics to determine internal forces and deformations and design accordingly.

(2) The design method provided by the specification cannot clearly give the characteristics of the structure under various external loads and its development law, and cannot reveal the process of internal force and deformation redistribution of the structure, so that the whole process cannot be evaluated more accurately. Structural reliability.

(3) The canonical calculation formula is only an algorithm to ensure safety, and it is not possible to calculate the stress or strain state at any point inside the structure under the normal use load.

The finite element analysis of reinforced concrete is an elastoplastic analysis method that combines the characteristics of reinforced concrete to overcome the above deficiencies so as to correctly reflect the actual characteristics of reinforced concrete structures. The finite element analysis method of reinforced concrete can give the whole process of the development of internal force and deformation of the structure: it can describe the formation and expansion of the fracture, as well as the failure process and its shape of the structure; it can evaluate the ultimate bearing capacity and reliability of the structure; The weak parts and links of the structure are used to optimize the design of the structure. At the same time, it can be widely adapted to various structural types and different stress conditions and environments. However, compared with the finite element method in general continuous homogeneous medium mechanics, there are still many difficulties in the finite element analysis of reinforced concrete structures. These difficulties mainly include:

(1) Reinforced concrete and concrete are composed of two materials with very different mechanical properties.

(2) Concrete materials are complex in nature. It is not only diverse in composition, it retains pores and white water after hardening, and even unhydrated cement particles form many microscopic cracks. Therefore, the stress-strain relationship of concrete is highly nonlinear and is seriously affected by its composition, forming process and use environment. Especially in the complex stress state and loading history, there are still many problems to be studied in the constitutive relationship of concrete.

(3) Under the load, the general reinforced concrete structure works with cracks, and these cracks change with the increase and decrease of the load and the passage of time.

(4) The deformation of concrete is related to time, such as shrinkage and creep, and its laws have yet to be studied in depth.

(5) The combination of steel and concrete can work together, mainly because of the bonding between the two. However, the relationship between adhesion and its relative deformation is complex and has many influencing factors. Due to limitations in measurement techniques, the constitutive relationship of bond slip is still an important topic of current research.

2. Mode of Nonlinear Finite Element Analysis of Reinforced Concrete Structures

The finite element analysis of reinforced concrete structures is identical to the finite element analysis of other solid materials in terms of basic principles and methods, but it has two unique outstanding features:

(1) The material constitutive relationship of reinforced concrete structures is special and complex;

(2) The discretization of finite elements has its special features.

Because reinforced concrete is composed of two materials and their properties are different, the characteristics must be considered when constructing the model by finite element analysis.

There are three main types of models that usually constitute finite element analysis of reinforced concrete: separate, combined, and monolithic.

2.1 Separate Model

Separate models treat steel and concrete as separate units. That is, steel and concrete are each divided into small enough units. In the plane problem, the concrete can be divided into a triangular unit, a quadrilateral unit, an isoparametric unit, etc., and the reinforcing bar can be divided into a triangular unit or a quadrilateral unit. Since the steel in the reinforced concrete structure is a slender material, its transverse shearing action can usually be neglected, so that the steel bar can be treated as a linear unit. This processing can greatly reduce the number of units.

In the separate model, there is also a special unit, which is the coupling unit between the steel and the concrete, which is used to simulate the bond and slip between the steel and the concrete. If the bond between the steel and the concrete is good and it is considered that it will not be relatively slippery, the two can be regarded as a rigid joint, and the joint unit can also be omitted. The coupling unit has two forms: 1 double spring coupling unit; 2 quadrilateral sliding unit.

2.2 Combined Model

In the combined model, there are two ways to use it most often. The first is a layered combination. This is done by dividing the concrete cross-section into a number of concrete and steel layers and making certain assumptions about the strain of the section (eg, the strain is linearly distributed along the section). The stiffness calculation formula of the unit can be derived from the actual stress-strain relationship and equilibrium conditions of the material.

Another combination method is to use an isoparametric unit. If there is no relative slip between the steel and the concrete, the two are in the same displacement field, and the displacement of each point can be determined by the displacement of the joint.

2.3 Monolithic Model

The holistic model of finite element analysis of reinforced concrete is to disperse the steel in the entire unit and treat the unit as a continuous homogeneous material.

3. Application of Nonlinear Finite Element of Reinforced Concrete Structure in Various Structural Analysis

In recent decades, the research on finite element analysis of reinforced concrete has been greatly developed. No significant progress has been made in analytical methods, theoretical basis and experimental research. At present, it can be said that it is quite practical in the structure. The analytical research of the project played a crucial role.

Chi Weisheng and others reasonably established the mechanical model of the shear force transfer between the first and second cast concrete interfaces in the nonlinear finite element analysis of the fabricated steel bar concrete structure; the simulation of the interaction between the first and second poured concrete interfaces was realized. . According to the nonlinear finite element program compiled by the model, the calculation of the completed assembly structure shows that the calculation results are in good agreement with the experimental data. It is shown that the established mechanical model of interface shear transmission is reasonable for the nonlinear finite element analysis of fabricated structures.

Zhang Wei discussed the finite element software ABAQUS in the finite element analysis of mass concrete from the nonlinear constitutive relation and failure criterion of concrete, the behavior after cracking, the constitutive relationship of steel bars, and the solution of nonlinear equations. Applications. Then combined with the model test data of the diversion tunnel of the Three Gorges Hydropower Station, the nonlinear analysis of reinforced concrete was carried out, and the results were compared with the experimental results to demonstrate the practical application ability of the finite element software ABAQUS. It is concluded that ABAQUS can be used in the nonlinear analysis of large-volume reinforced concrete. Separate or buried steel bars can be used; nonlinear equations can be solved by Newton-Raphson method or quasi-Newton method. At the same time, the infinite norm of force and displacement is used as the convergence criterion. Compared with the large scale model test results of the pressure pipeline of the Three Gorges Hydropower Station, during the loading process, the calculation results can basically reflect the load effect history of each material of the test model. The main difference between the two is that the calculation of the initial cracking load is too large, the failure load is too small, and the steel stress also has a certain difference. The main reason is that the program uses a distributed crack model, and the actual cracks are discontinuously distributed, which is a category of discontinuous media. How to better simulate the crack development process from numerical analysis is a problem that needs further study.

Zhang Yaoting and Qiu Jisheng used the finite element software ANSYS to analyze the nonlinear analysis of five external prestressed concrete beams, and compared the calculated values of ANSYS with the measured values. The results show that the method has high precision and is proposed for simulating the mechanical performance of reinforced concrete structures. Some suggestions: According to the analysis, for the cracked concrete member, the elastic modulus and the moment of inertia can be reduced and then calculated as an elastic material. The reduction of the moment of inertia can use the effective moment of inertia instead of the moment of inertia to simulate the effect of the development of the crack on the stiffness of the beam. When the concrete stress is large, the concrete has entered the elastic-plastic stage, and the initial elastic modulus can not correctly reflect the stress-strain property at this time. In this case, the secant modulus should be used instead. It is generally considered that the secant modulus E, c of the cracked section is 0.5 times of its elastic modulus Ec. For the whole beam, some sections have been cracked, and some have not yet cracked, so the elastic modulus reduction factor Vc should be greater than 0.5. Less than 1. Because the location of concrete section cracking is difficult to determine, the strain of concrete is different, so it is difficult to accurately determine the value of Vc. According to the nonlinear analysis results of externally prestressed concrete beams, it is recommended to crack in concrete. After Vc takes a value between 0.6 and 0.7, but the practicality and accuracy of this coefficient for other reinforced concrete structures have yet to be verified by more analysis.

Li Liwen summarized the properties of reinforced concrete structural materials and the significance of nonlinear finite element analysis, and applied the nonlinear finite element analysis of wide-leg T-shaped columns under monotonic loading using ADINA software to study the strain and load of the wide-leg T-section column. In the case of change, when the axial pressure is relatively low, the cross-section performance of the wide-arm T-section column is controlled by the bending moment as the main internal force. The damage of the test piece is basically the bending-shear-shaped failure, and the flat-section assumption is still applicable. The conclusion is consistent. It is proved that the application of concrete nonlinear finite element analysis can simulate the nonlinearity of concrete and steel materials well, and simulate the whole process from force to failure.

Feng Ran and Zhang Xianjin conducted a nonlinear finite element analysis of the reinforced concrete two-way thin plate subjected to concentrated load under normal service limit conditions. The relevant program design was carried out according to the derived calculation formula, and the results and linear elasticity of the analysis with ANSYS software. The theoretical calculation results of the small deflection of the thin plate are compared with the experimental results, and the feasibility of the method used is demonstrated. At the same time, it is proposed that in the nonlinear finite element analysis, the finer the mesh is, the smaller the load increment is set, and the more accurate the calculation result is, but the number of iterations will increase accordingly, and the system resources and computer consumed. The more time, the more the advantages and disadvantages should be weighed according to specific issues.

4. Conclusion

The nonlinear finite element analysis of reinforced concrete structures, with the deepening of theoretical research and the rapid development of electronic technology, the technical means are more and more advanced, and the development is promising. From the introduction of the previous article, it can be seen that the numerical simulation of finite element analysis in structural engineering provides an important basis for structural design, but there are still many problems, which remains to be solved by the researchers. Practical direction.

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