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Basic Problems and Applications of Finite Element Method

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Abstract

The finite element method is a highly efficient and commonly used numerical calculation method. In 1965, the term ' finite element ' first appeared. After more than 30 years of development history, the theory and algorithm have been increasingly improved. Nowadays, finite element is widely used in engineering. This paper first introduces the common knowledge of finite element and introduces the common problems in finite element. Secondly, it introduces the steps of finite element solution and its application in engineering. Finally, it gives the application of two-dimensional foundation pit in finite element under GTS NX software.

Keywords

Finite element method; gTS NX; deep foundation pit.

1. FOREWORD

The finite element method is an efficient and commonly used numerical calculation method. Its basic idea is to transform the given Poisson equation into the extreme value problem of solving the functional. The finite element method was developed on the basis of variational principles in the early days, so it is widely used in various physical fields described by Laplace equations and Poisson equations (such fields are closely related to the extremum problems of functionals). Now the finite element method has been used in various fields.

2. COMMON PROBLEMS IN FINITE ELEMENT.

2.1. Principle of minimum potential energy and principle of virtual work

The principle of minimum potential energy means that when the potential energy of a system is the smallest, the system will be in a stable equilibrium state. The principle of minimum potential energy is essentially consistent with the principle of virtual work. The minimum potential energy principle is a special case of the potential energy principle in the linear elastic range. For general problems, the real displacement state makes the potential energy of the structure take a stationary value, and the minimum value is taken in the linear elastic problem. In the finite element theory, the principle of minimum potential energy is that the displacement of the equilibrium differential equation is satisfied so that the potential energy is minimized when all the displacements satisfy the given boundary conditions. When solving the finite element displacement, the displacement result of the displacement finite element is always lower than the real one.

2.2. Element type in finite element

From the geometric shape and continuity requirements, the finite element method has the following types.

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(1) One-dimensional element; such as rod element, beam element, axisymmetric element, etc. The form is a straight line or a curve, or a linear element with a certain shape.

(2) Two-dimensional unit; for example, shell element, plate element, plane element, axisymmetric solid element, composite shell element and so on are in the form of a plane or surface.

(3) Three-dimensional unit; such as solid element, thick shell element, etc. The form is a tetrahedral pentahedron hexahedron with three dimensions of space[6].

2.3. Advantages of isoparametric element

Isoparametric unit; if the order of the shape function used in the element coordinate transformation and the displacement function is equal, the number of nodes used to specify the shape of the element is equal to the number of nodes used to specify the displacement of the element. This element is called an isoparametric element.

Through coordinate transformation, the integral region is transformed between 1 and 1, which is convenient to use the standardized numerical integration method to obtain the element stiffness matrix and equivalent node load. In this way, high-precision elements with irregular shapes can be used, that is, to adapt to the curve and surface boundaries, and to obtain better accuracy.

Advantages of isoparametric element:

(1) It has a wide range of applications, such as plane or space continuum, bar structure and plate and shell problems.

(2) After changing the irregular element into regular element, it is easy to construct the displacement mode.

(3) Irregular elements can be used in the original structure, which is easy to try the shape of the boundary and change the size of the element.

(4) The nodes can be flexibly increased or decreased, and it is easy to construct various transition elements.

(5) The derivation process is universal, one-dimensional, two-dimensional, three-dimensional basically the same[6].

3. SOLVING STEPS OF FINITE ELEMENT METHOD

For the finite element method, the solving steps can be summarized as :

(1) Establish the equation; according to the variational principle or the orthogonalization principle of equation remainder and weight function, the integral expression equivalent to the initial boundary value problem of differential equation is established, which is the starting point of finite element method.

(2) Subdivision of regional units; according to the shape of the solution region and the physical characteristics of the actual problem, the region is divided into several interconnected and non-overlapping units. The division of the regional element is the preliminary preparation work of the finite element method. This part of the workload is relatively large. In addition to numbering the calculation unit and the node and determining the relationship between each other, it also represents the position coordinates of the node. At the same time, it is necessary to list the node serial number and the corresponding boundary value of the natural boundary and the essential boundary[9].

(3) Determine the unit basis function; according to the number of nodes in the element and the requirement for the accuracy of the approximate solution, the interpolation function satisfying certain interpolation conditions is selected as the element basis function. The basis

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functions in the finite element method are selected from the elements. Since each element has a regular geometric shape, certain rules can be followed when selecting the basis functions[7].

(4) Unit analysis; the solution function in each element is approximated by the linear combination expression of the element basis function. Then, the approximate function is substituted into the integral equation, and the element region is integrated to obtain an algebraic equation group with undetermined coefficients (i.e., the parameter values of each node in the element), which is called the element finite element equation.

(5) Overall synthesis; after the element finite element equation is obtained, all the element finite element equations in the region are accumulated according to certain rules to form the overall finite element equation.

(6) Treatment of boundary conditions; there are three forms of general boundary conditions, which are divided into essential boundary conditions, natural boundary conditions and mixed boundary conditions. For natural boundary conditions, it can be automatically satisfied in the integral expression. For the essential boundary conditions and mixed boundary conditions, it is necessary to modify the overall finite element equation according to certain rules to meet[10].

(7) Solving the finite element equation: The overall finite element equations modified according to the boundary conditions are closed equations containing all unknowns. The function value of each node can be obtained by using appropriate numerical calculation method[7].

4. THE APPLICATION OF FINITE ELEMENT IN CIVIL ENGINEERING

4.1. Application of finite element software in bridge engineering

In order to achieve bridge safety design and bridge safety control, it is necessary to establish an appropriate model of the bridge to simulate the various dynamic responses of the bridge under the action of external forces. Only careful and accurate analysis of the bridge can achieve the goal of bridge design safety and bridge control safety[11].

Bridges are subjected to many external forces in daily life, including accidental loads, permanent loads, etc. The influence of these loads on the bridge is different, and the bridge will deform to varying degrees under the action of these loads. In the design of the bridge, ANSYS is used to simulate the force acting on the bridge[1]. The application of ANSYS in bridge design can make people better understand the deformation of the bridge and the size of the deformation in the direction of the force. The factors that can affect the bridge include the creep of concrete, the cracking of concrete, and the tightness of steel bars. Through the analysis of these factors, ordinary software can no longer meet the requirements. ANSYS software has powerful functions, which can meet the needs of users to establish models, and can use computer technology to obtain corresponding results[8].

4.2. Application of finite element software in dam engineering

In the process of dam design, it is necessary to carry out the simulation calculation of the dam. This process is complicated and it is difficult to draw reliable conclusions. The application of computer technology in civil engineering has greatly facilitated people's calculation. People can realize the fast and simple calculation by developing corresponding software. The finite element software can be used to realize the simulation calculation of the dam, which saves a lot of manpower, material and financial resources. The safety of dams is very important in real life. The types of forces on dams, especially gravity dams, are static. The water pressure, the impact force caused by water flow, and the accidental load also include the increased load caused by the increase of rainwater. ANSYS can vividly show the deformation of the dam under load. The force acting on the dam at different water depths is different. With the increase of depth, the

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pressure on the dam is greater. By using the finite element software to simulate, we can fully understand the stress and strain of the dam at different depths. Through the simulation of finite element software, the effect of water flow at different depths on the dam and the permeability coefficient of water flow in the main parts of the dam can be obtained. This plays a key role in dam design and safety control.

4.3. Application of finite element software in foundation pit engineering

The rapid development of the city has brought a large number of foundation pit projects with large area and deep depth. Numerical simulation of these foundation pit projects is helpful for people to choose the appropriate way to support the deep foundation pit, and can simulate the settlement value of the deep foundation pit project. It is helpful to carry out safety checking calculation in the design of deep foundation pit engineering and ensure the safety of deep foundation pit and its surrounding buildings. ANSYS also plays an important role in foundation pit support. The influence of the load around the foundation pit on the safety of the foundation pit can be simulated by ANSYS software. The results simulated by ANSYS can determine what kind of bolt support method is used in the foundation pit support and what type of bolt is selected. Different anchors have different results for the support of the foundation pit. The safety of the foundation pit is not only related to the safety of many people 's lives, but also affects the construction progress of the project to a large extent.

4.4. Application of finite element software in concrete reinforcement

In the process of using ANSYS modeling, solid65 unit is selected. In the design of reinforced concrete structure, the safety and durability of the structure and the reliability of the structure design need to be considered. The simulation of the finite element software can obtain the information of the stress and strain of the structure. It can also show the slow change of the structure under the action of external force in a three-dimensional way, which includes the development process of deformation. It is helpful to continuously improve the performance of the structure in the design process, control the setting of design parameters, and ensure the safety, applicability, durability and economy of the structure. The steel bars in the concrete structure should be designed with reference to the relevant specifications[12]. Although the reinforced concrete structure in the design of the relevant software, however, people also can through the ANSYS finite element software to carry out the relevant simulation deduction. By setting the relevant material parameters in ANSYS software.Such as Poisson 's ratio, tensile strength, etc. It can calculate the displacement change of reinforced concrete structure in the direction of external force and the displacement change in the horizontal direction under the action of external force. Through the division function of ANSYS grid, we can also observe the distribution of internal reinforcement of reinforced concrete structure under the design of ANSYS software. These are the great convenience brought by ANSYS software. It is helpful to better grasp the closed value of reinforcement strength, make full and reasonable use of reinforcement to design, better grasp the project cost, improve the technical means of design and improve the quality level of design[2].

5. MIDAS APPLICATIONS

5.1. Engineering background

The northwest side of the foundation pit is about 55 m away from Century Street, the south side is about 50 m away from Jingyue Street, and the west side is about 90 m away from a roundabout road. The east side is the pre-built residential building of the project, and there is a − 1F basement. The nearest distance is about 20 m away from the project, and there are 3F buildings 25 m away from the southeast side. The independent foundation is used, and the buried depth is 3.0 m below the ground, 15 m away from the project[3]. In addition, according

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to the survey, there are underground pipelines under the project, and attention should be paid to the construction[4]. The surrounding environment of the foundation pit is shown in Figure 1. The stratigraphic conditions are shown in Table 1.



Figure 1. Surrounding environment of foundation pit

Table 1. Stratigraphic conditions

level number	soil type	gravity	angle of internal friction φ	force of cohesion c	the thickness of the layer
1	miscellaneous fill	18.0	10.0	12.0	3.5
2	silty clay	18.5	10.1	30	2.0
3	silty clay	18.5	9.0	25	4.5
4	coarse sand	21.0	35	3	3.0
5	complete-intense weathering mudstone	20.0	20	50	2.0
6	strong weathered mudstone	21.0	25	60	7.2

5.2. Establish numerical simulation

The simulation is carried out in 2D form. The specification is 70 × 70 m, and the support form is pile anchor support. The foundation pit is 10 m deep, the pile length is set to 20 m, and two rows of anchor rods are set. The first layer is 4 m in the foundation pit, 13 m long, and the second root is 8 m long, 16 m long. The inclination angle of the bolt is 15 °, and the vertical spacing and horizontal spacing of the HRB400 steel bar are 1.5m. The model is shown in Fig.2.

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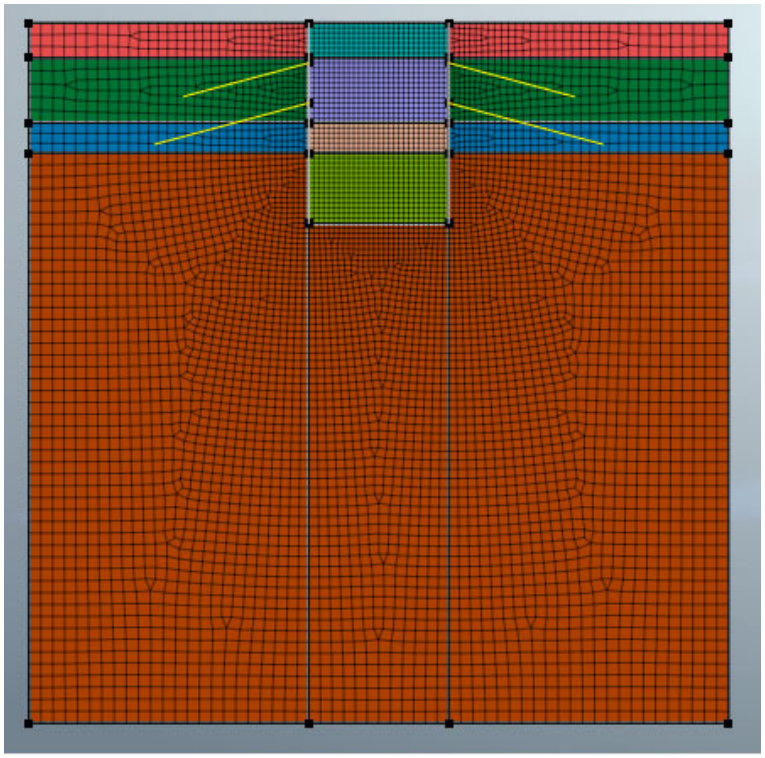


Figure 2. Two-dimensional foundation pit model diagram

The boundary conditions of the model are set, including self-gravity and upper load force. The force of the model is shown in Fig.3. The minimum force is about the top of the pile, and the maximum is at the bottom of the foundation pit[5].

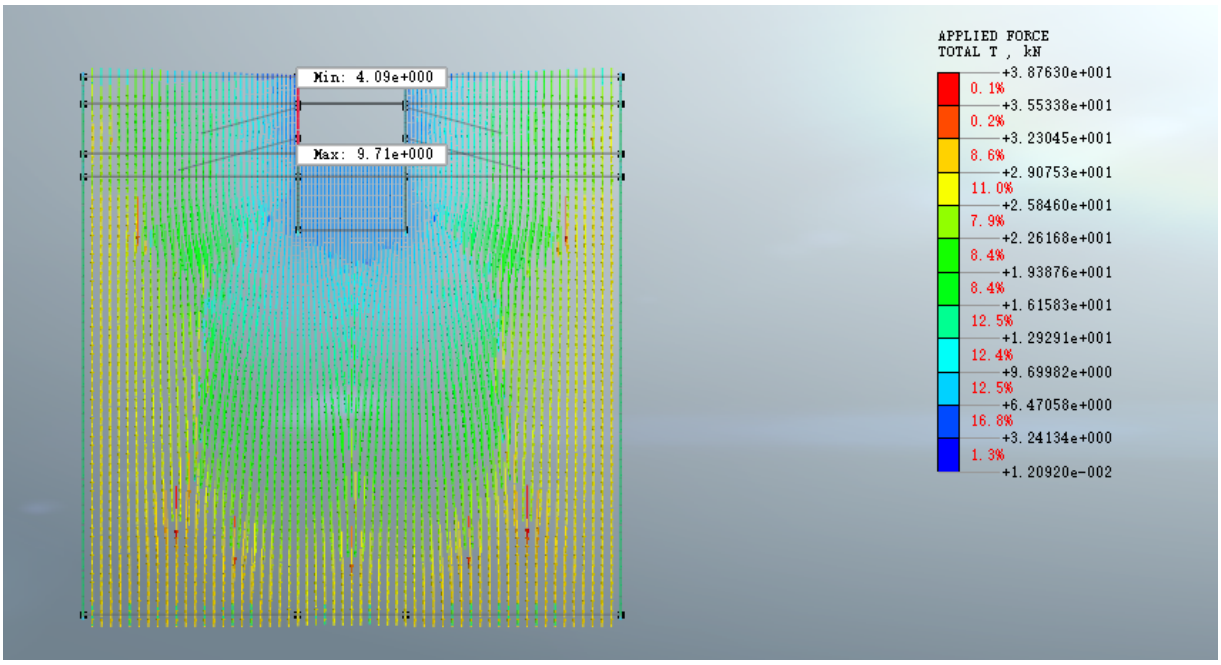


Figure 3. Two-dimensional foundation pit stress diagram

The settlement at the top of the foundation pit is particularly important for the foundation pit. As shown in Figure 4, the maximum settlement of the foundation pit is 9mm and the minimum is 0.4mm.

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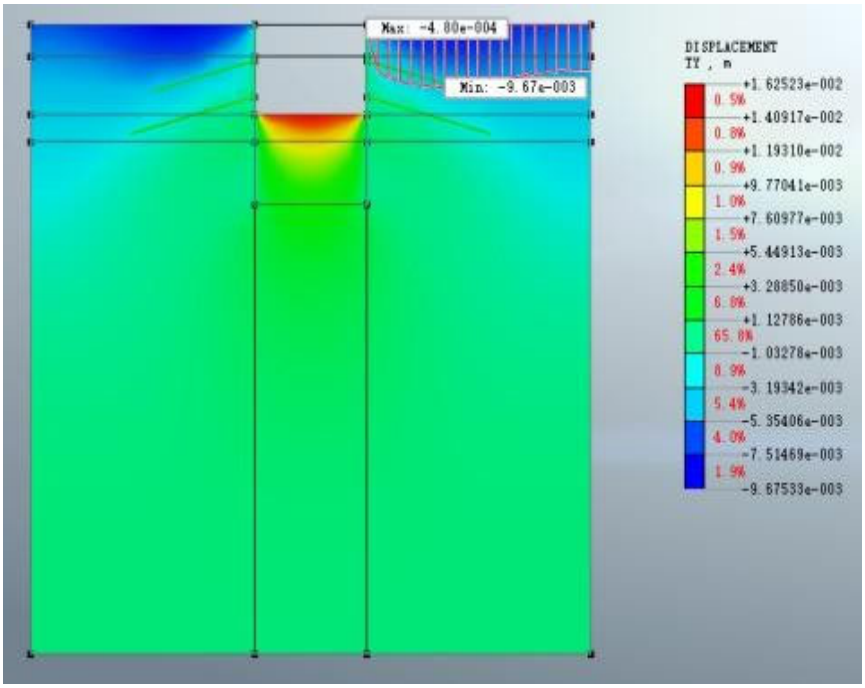


Figure 4. Vertical displacement diagram of foundation pit

6. CONCLUSIONS

The finite element method is generally from the unit to the whole, and then the whole to the unit. Its core is to establish the equation to solve the unit body, and finally get the whole solution. The application of finite element software in civil engineering greatly facilitates people 's design. It is a typical example of the combination of computer technology and civil engineering. It is greatly convenient and convenient for civil engineering projects. It is also a big step in the combination of computer and civil engineering. From the perspective of its future development direction, the finite element method will be more mature and applied to various projects.

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