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Finite element analysis of flexural behavior of textile reinforced concrete slab

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Abstract: Order to investigate the failure effect of textile reinforced concrete (TRC) plate under bending load, the corresponding finite element model is established. By comparing the numerical simulation results with the experimental results, the rationality and feasibility of the finite element model are verified, and then the crack extension of TRC and the ultimate strain of carbon textile are analyzed. The failure mode of the slab under bending load is obtained, and it is found that the carbon textile concrete slab has better reinforcement effect, which greatly improves the safety performance of concrete members.

1 Introduction

With the development of economy, concrete structure is widely used in building structure. However, due to the shortcomings of low tensile property and brittleness of concrete[1-2], researchers at home and abroad have carried out experiments and researches on the performance of textile reinforced concrete. In recent years, with the improvement of fiber preparation technology, researchers try to use all kinds of chopped fiber and textile to enhance the performance of concrete. Xunyong[3] and others have carried out the experimental research on the flexural performance of fabric reinforced concrete slab, and the research shows that the fabric reinforced concrete slab has high flexural capacity and good deformation capacity. With the increase of fiber content, the flexural capacity and midspan displacement of Carbon fiber reinforced concrete slab increase[4]. Xu Shizhen et al[5]. used epoxy resin coating and sand bonding treatment to enhance the flexural capacity of concrete slab. The results show that the cracking load and ultimate load can be increased by prestressing the carbon fiber, and the durability and service performance of the structure can be improved.

Based on the finite element simulation of the mechanical properties of fiber reinforced concrete, combined with the flexural performance test of carbon fiber and wire netting reinforced concrete slab carried out by reference, the flexural capacity of wire netting and textile reinforced concrete slab is analyzed by finite element analysis, and compared with the experimental data, the simulation results of the flexural capacity of the structure and the mid span displacement of the slab are obtained.

2 Finite element simulation

2.1 Finite element model selection and material parameters

In this paper, ABAQUS finite element simulation software is used to simulate the experiment, and the post-processing is compared with the experimental results.

In terms of concrete, the concrete plastic damage model is used for concrete materials, according to the national standard code fordesign of concrete structures (GB 50010-2010). The parameters of uniaxial tension, uniaxial compression and damage factor are defined by the stress-strain formula curve of uniaxial tension and compression[6], and the grid element is defined as C3D8R, which is suitable for simple contact problems of geometric structures.

In terms of wire netting, it can be seen from many trial calculations in ABAQUS thatNo.10 wire netting adopts linear strengthening elastic-plastic model, and there is no stiffness degradation in the material. When the load is received, the iron wire is stretched until it enters the plastic stage, and finally breaks. Therefore, the double diagonal model should be used in the numerical model established in this paper. The element is a three-dimensional truss four node element (T3D2).

In terms of textile, the linear elastic constitutive model is used to simulate the bi-directional fiber bundle of carbon textile in thispaper, and the element property is also selected as T3D2 element. When the fiber bundle stress reaches the ultimate strength, it is judged that the fiber bundle is broken, and this mode is used to determine the fiber failure.

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2.2 Model verification

2.2.1 Entity model establishment

The accurate establishment of the specimen model is the basis of the finite element simulation. The flexural experimental model of the textile and wire netting reinforced concrete thin slab is shown in Figure 1. The establishment of the gasket model at the loading point is mainly to prevent the concentrated load, which leads to the excessive stress concentration at the loading point and the support, so the simulation results are not consistent with the actual situation.

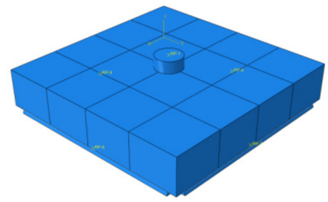

Fig.1. Basic model drawing

2.2.2 Definition of material parameters and load constraints

According to the code for mix proportion design of ordinary concrete (JGJ55-2011), C30 benchmark concrete is designed. The wire isNo.10 wire and the carbon fiber is unidirectional carbon fiber cloth. The material parameters are shown in Table 1.

Table 1.performance parameters of carbon fiber

Materials	tensile strength （MPa）	modulus of elasticity under tension （GPa）	elongation （%）	density （kg/m^2）	cross sectional area of unit bundle （mm^2）
fiber bundles	3449	248	1.79	1780	2.4

The unit selection of this model has been detailed in Chapter 1.1, and the concrete constitutive parameters are shown in Table 2. The separated modeling method is used in the modeling process of carbon textile, and the mechanical behaviors of concrete, wire netting and carbon fiber fabric are independent of each other.

This paper ignores the influence of the interface performance between wire netting, fiber fabric and concrete, and uses the embedded element method in ABAQUS to simulate the interaction between them. The method considers that there is norelative slip between the fabric element and the concrete element of the model, and the node displacement of the fabric inthe concrete element is obtained by interpolating the node displacement of the concrete element, and the mechanical relationship between them is established by the displacement compatibility condition.

Table 2. parameters of CDP model

ψ /(°)	$\in$	σ_{b0}/σ_{c0}	K_c	μ
30	0.1	1.16	0.6667	0.0005

The loading mode is displacement loading control, and the loading diagram isshown in Figure 2. Through the establishment of the cushion block with large stiffness, the coupling method is adopted to combine with the main body model, the concentrated force load is applied at the loading point, that is, the central part of the loading gasket. The loaded gasket and four side support are simplified as rigid body to ensure no deformation. In the boundary condition, the line constraint is applied at the support of the model, that is U1 = U2 = U3 = 0.

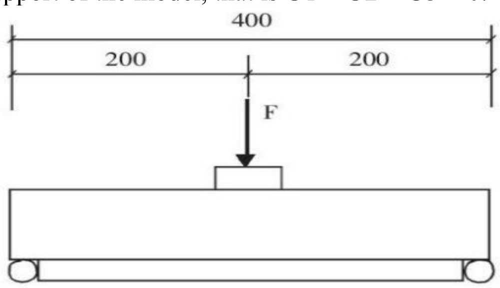

Fig.2.loading diagram of simply supported slab on four sides

3 Analysis of finite element calculation results

3.1 data comparison

Through the above model establishment and test, the finite element analysis of plain concrete (P0), wire netting reinforced concrete (WP-100) and textile reinforced concrete (CP-100) thin plates was carried out. Table 3 shows the comparison between the experimental data and the simulation data, and it can be seen that the errors are within the allowable range.

Table 3. Comparison of experimental and simulation data

specimen number	experimental materials		ultimate load（KN）	midspan displacement（mm）

C0	plain concrete P0	experimental value	21.3	0.91
		simulation value	22	1.03
C1	wire netting reinforced concrete WP-100	experimental value	29	1.98
		simulation value	26.1	1.75
C2	textile reinforced concrete CP32-100	experimental value	40.5	3.56
		simulation value	42	3.25

3.2. failure mode and load displacement curve

Through the finite element simulation, the maximum principal plastic strain nephogram and corresponding load displacement curve of different specimens are obtained.

(1) It can be seen from figures 3 and 4 that during the failure process of C0, the load and displacement increase linearly until the brittle failure of concrete occurs. The crack mainly extends in the direction of longitude and latitude.

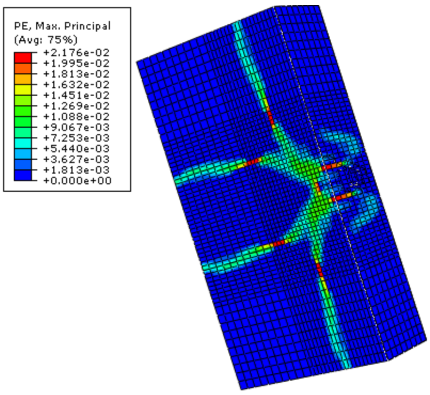

Fig.3.maximum principal plastic stress of C0

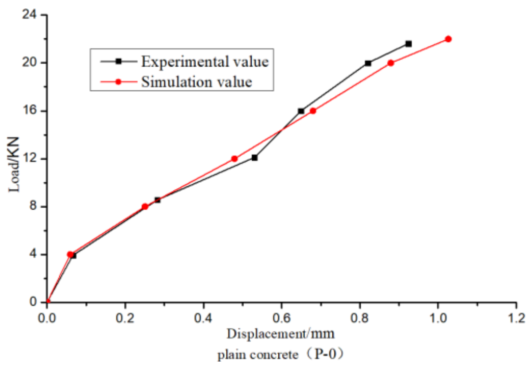

Fig.4.load displacement curve of C0

(2) Figures 5, 6 and 7 show that under the action of flexural capacity, C1 is first worked by wire netting and concrete. At this time, the flexural load and midspan displacement increase linearly. With the increase of load, the concrete in tension zone will crack, which is called crack load. At this time, the wire netting will yield, the flexural capacity will decrease, the crack will extend in an oblique direction, and finally the specimen will be destroyed.

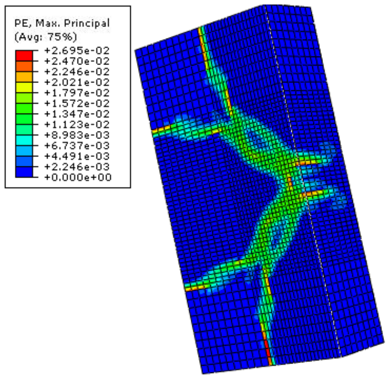

Fig.5.maximum principal plastic stress of C1

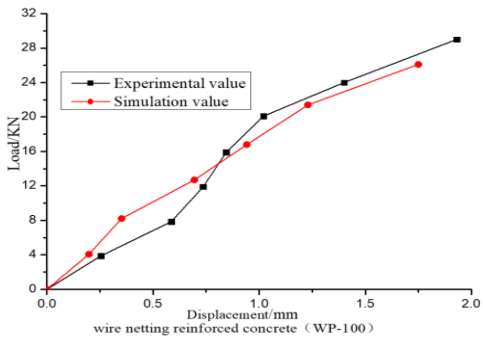

Fig.6.load displacement curve of C1

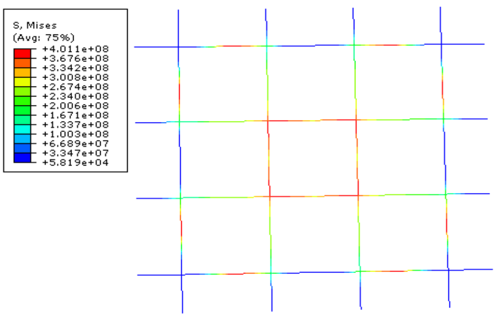

Fig.7.equivalent stress nephogram of wire mesh

(3) In Figures 8, 9 and 10, when C2 specimen is loaded, flexural load and midspan displacement increase linearly. With the increase of load, cracks spread from the center to the surrounding of concrete in tension zone, and continue to load. At this time, the load is mainly borne by carbon textile, and the cracks extend along the direction of longitude and latitude. The flexural capacity reaches the maximum when the woven fabric reaches the stress limit, the carbon textile begins to fracture, and finally the specimen fails.

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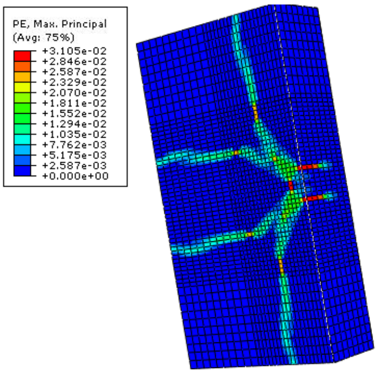

Fig.8.maximum principal plastic stress and tensile damage distribution diagram of C2

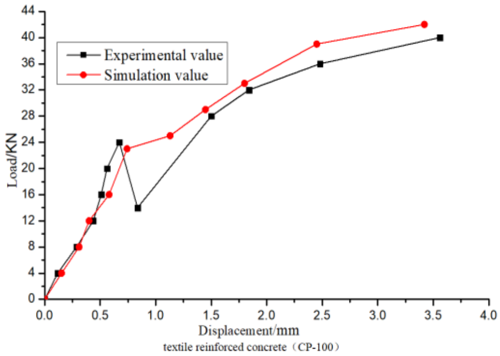

Fig.9.load displacement curve of C2

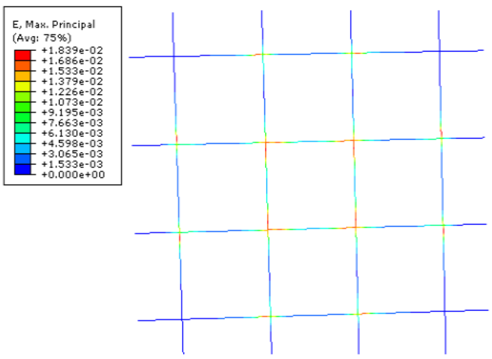

Fig.10.maximum strain nephogram of textile

4 Conclusion

(1) From the flexural effect of concrete slab, the flexural capacity and mid span displacement of concrete slab reinforced by carbon textile and wire netting are significantly improved, and the carbon fiber reinforced effect is the best.

(2) From the perspective of the number of layers of carbon textile, with the increase of the number of layers, the flexural capacity of carbon textile reinforced concrete members increases. When the number of layers increases to a certain number, the flexural load growth of carbon textile reinforced concrete members becomes unclear.

(3) From the point of view of failure characteristics, the failure cracks of carbon fiber and wire netting reinforced concrete slab develop from oblique to longitude and latitude, and the failure effect is better than that of plain concrete slab. Compared with wire netting, textile has better reinforcement effect and can improve the damage effect of concrete slab.

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