Experiment and Research on Safety Performance Analysis of Green Concrete Based on Abaqus

Yi Wang*

School of Urban Construction, Beijing City University, Beijing, China

*Corresponding author: vvyyy_04@outlook.com

Abstract. Traditional concrete has weak compressive and tensile strength and low durability, which requires regular maintenance. As a new environmental protection building material, green concrete can effectively improve the compressive and tensile properties and durability of traditional concrete by introducing recycled materials and fiber-reinforced materials in the preparation process. This paper is to explore the safety performance of green concrete. The constitutive model, elastic modulus, Poisson's ratio and other data of green concrete were searched by literature. Excel was used to calculate and integrate the data, and the model was built in Apaqus software for safety test research. The research shows that: The compressive stress-strain curves of steel fiber reinforced concrete and ordinary concrete are similar to the standard curves. The deformation resistance of steel fiber reinforced concrete is stronger than that of ordinary concrete. The displacement change of ordinary concrete under the action of applied force is larger than that of steel fiber concrete, and the strength of steel fiber concrete is stronger than that of ordinary concrete. This paper can provide the corresponding data suggestions and help with the selection of materials in building construction.

Keywords: Green, safety, concrete.

1. Introduction

With the development of the times, people have higher standards for building safety. As an indispensable building material in construction engineering, concrete is widely used in the construction field. In recent years, with the development and renewal of buildings, a large amount of construction waste is also generated, which cannot be rapidly degraded in the city. It is always affecting the environment of people's lives, so the environmental pollution caused by construction waste can not be underestimated. Therefore, it is of great significance to develop green building materials with excellent performance and environmental friendliness.

As one of the most common building materials, "green" concrete can effectively reduce the impact of waste on the environment during the preparation and construction phase. To promote low-carbon environmental protection and the secondary utilization of waste, Zhang Jianhuan et al. [1] studied the mix ratio and structural mechanical properties of natural plant fiber recycled concrete, and analyzed and compared it with ordinary concrete. It provides a numerical reference for the construction field and also provides a research direction for the development of green concrete. Wang Jianbao et al. conducted a study in which waste rubber powder was crushed and treated to mix with concrete to form high-performance "green" environmentally friendly concrete. Reduce the environmental pollution of rubber which is difficult to degrade. Research and analysis show that the bending mechanism of recycled rubber concrete is almost similar to that of ordinary concrete beams, indicating that this high-performance concrete can be used instead of ordinary concrete in future development [2]. Bai Chenmeng et al. have also done a study using Abaqus for structural mechanics analysis. The factors influencing the fracture of steel fiber reinforced concrete are analyzed [3]. Abaqus software is widely used in structural mechanics analysis, especially in concrete. Research on "green" concrete is also increasing. This paper explores the difference in structural mechanical properties between green concrete and ordinary concrete. This is because steel fibers have a favorable effect on strain hardening and various cracking behaviors [4], and steel fibers usually exist in short, discontinuous forms in concrete. This improves the durability of the inherently brittle concrete [5]. Therefore, the experimental modeling and experimental loading analysis were carried out by using

Abaqus software. The cubic compressive strength and axial compressive strength of the two types of concrete are analyzed, which can make the relevant people in the construction industry more understanding of green concrete, and provide the corresponding numerical reference for the construction field.

2. Experimental Overview

2.1. Green Concrete

Green concrete is to maximize the material utilization rate of concrete in production practice. By reducing the amount of material or adding different types of additives, the safety performance of concrete exceeds the strength of the original concrete. Green concrete is divided into green high-performance concrete, recycled aggregate concrete, and environmental protection concrete. Nowadays, due to the large amount of construction waste elimination, it can not be used again. The research of green concrete by experts in relevant fields at home and abroad has made remarkable progress. In the selection of raw materials, in order to reduce the carbon emissions generated in the production process of concrete, researchers are constantly exploring new environmentally friendly materials. For example, additives such as fiber and recycled aggregate are mixed in concrete to form a new high-performance green concrete. This increases the strength and durability of concrete; The use of industrial waste resources and recyclable wastes; And low emission of harmful substances. In practical applications, now green concrete has been used in various construction projects. In line with the concept of low carbon, environmental protection, and carbon neutrality [6].

2.2. Experimental Model Construction

2.2.1 Concrete strength grade selected

Ren et al. obtained a functional relationship between αc and the characteristic parameter λf of fiber content. According to the data, when λf is equal to 1, the corresponding αc is equal to 2. 45. According to the formula of αc in the literature, it can be calculated that when the strength grade of concrete is C90, the value of αc obtained by taking λf as 1 is 2. 468[7-9]. The above theoretical analysis shows that C90 concrete is the most suitable material for the experiment, but in the experiment, it is found that its inelastic strain and damage calculation appear negative values. In AK et al. 's experiment, the compressive strength of BA concrete after 28 days of curing was between 42-47. 5MPa. The compressive strength of BASF concrete after 28 days of curing is between 47. 5-56. 26MPa. The compressive strength of BAGF concrete after 28 days of curing is between 47. 5-54. 29MPa [10,11]. Therefore, concrete with a strength grade of 50 is selected for this experiment.

2.2.2 Construction of cube compressive strength model

As the most basic concrete performance index, the cube compressive strength divides the strength grade of concrete. According to the "concrete structure design Code" (GB50010-2010)[8]. When testing the compressive strength, if the cube side length of the standard specimen is 150mm×150mm×150mm, it can be used as the standard test block for the experiment. The test block model is constructed in the Abaqus soft interface.

2.2.3 Construction of axial compressive strength model

In actual construction projects, the axial compressive strength is usually used as the standard value of compressive strength for design and calculation [7]. In order to be more appropriate to the actual construction project, the prismatic test block model is constructed in Abaqus software. According to the "concrete structure design Code" (GB50010-2010). When testing the compressive strength of the axis, if it is a non-standard specimen, a 100mm×100mm×300mm prismatic body can be used as the standard test block for the experiment.

3. Constitutive Model of Green Concrete

3.1. Constitutive Model of Steel Fiber Reinforced Concrete

3.1.1 Uniaxial compression constitutive

There are many functional expressions of concrete uniaxial compression constitutive at home and abroad, and at home, the most common domestic concrete compressive stress-strain curve is shown in Fig.1.

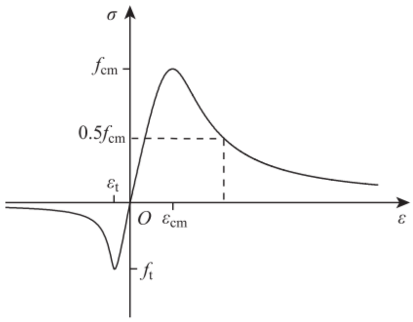

Fig. 1 Stress-strain curve of concrete [6]

According to the "Concrete Structure Design Code" (GB50010-2010), the constitutive formula of ordinary concrete under uniaxial compression is:

$$d_t = \begin{cases} 1 - \rho_t[1.2 - 0.2x^5] & x \le 1 \\ 1 - \frac{\rho_t}{\alpha_t(x-1)^{1.7}+x} & x > 1 \end{cases} \quad (1)$$

Where, α_t ——— Reference value of concrete uniaxial tensile stress-strain curve decline;
$\varepsilon_{t,r}$ ——— Peak compressive strain of concrete corresponding to uniaxial tensile strength;
d_t ——— Evolution parameters of concrete uniaxial tensile damage.

Steel fiber concrete is mixed with steel fiber based on ordinary concrete, and its constitutive model changes accordingly. According to the literature, the constitutive formula of steel-fiber concrete under uniaxial compression is as follows [7] :

$$\alpha_c = \frac{88.75{f_{c,r}}^{-0.76}}{1+0.51\lambda_f} \quad (2)$$

The constitutive model of steel fiber reinforced concrete is obtained by introducing αc into the constitutive model of ordinary concrete. Formula 2-6 is the characteristic value of steel fiber content. In the experiment, the volume parameters of steel fibers were selected as 0, 0. 5, 1, and 1. 5[9]. The experiment shows that when the volume parameter of steel fiber is 1. 5%, the compressive strength of fiber reinforced concrete reaches the maximum [10]. When the volume parameter of steel fiber is 2%, the splitting compressive strength and fracture modulus of fiber reinforced concrete increase. Therefore, the initial value of λf in this experiment is 0. 1% and the final value is 2. 02%. The symbols have the same meaning as above.

3.1.2 Uniaxial tension constitutive

When steel fiber is added into ordinary concrete, its properties change greatly. The degree of tension changes obviously. "concrete structure design Code" (GB50010-2010)It can be seen that the uniaxial tension constitutive formula of ordinary concrete is as follows:

$$d_t = \begin{cases} 1 - \rho_t[1.2 - 0.2x^5] & x \le 1 \\ 1 - \frac{\rho_t}{\alpha_t(x-1)^{1.7}+x} & x > 1 \end{cases} \quad (3)$$

α_t ——— Reference value of concrete uniaxial tensile stress-strain curve decline;
$\varepsilon_{t,r}$ ——— Peak compressive strain of concrete corresponding to uniaxial tensile strength;
d_t ——— Evolution parameters of concrete uniaxial tensile damage.

According to the literature, the uniaxial tension constitutive formula of steel fiber reinforced concrete is as follows [7] :

$$\alpha_t = \frac{8.02\times10^{-4} {f_{t,r}}^2}{1+0.15\lambda_f} \tag{4}$$

The constitutive model of steel fiber reinforced concrete is calculated by bringing it into the tensile constitutive model of ordinary concrete. The meanings of the symbols are the same as above.

3.1.3 Other data reference

Other data reference$\varepsilon_{c,r} = (700 + 172\sqrt{f_{cu}}) \times 10^{-6}$; The peak strength corresponds to the strain under tension$\varepsilon_{t,r} 65 f_{t,r}^{0.54} \times 10^{-6}$. $E_c = \frac{10^5}{A+(B/f_{cu})}$ among A=1. 24, B=146. 9.

The expansion Angle of ordinary concrete ψ , eccentricityc, σ_{b0}/σ_{c0} , K_c , The viscosity coefficients are 30, 0. 1, 1. 16, 0. 667, 0, while those of steel fiber reinforced concrete are 30, 0. 1, 1. 16, 2/3, 1e-5.

4. Compare and Analyze the Safety Performance

In this experiment, the safety performance of concrete is judged from two aspects: the compressive strength of the concrete cube and the compressive strength of the concrete axis. The stress-strain relationship of two kinds of concrete under the same conditions is analyzed. The axial compressive strength is designed and calculated as the standard value of compressive strength in construction engineering. The axial compressive strength can also further determine the relationship between force and displacement. Observing the compression shape variable of two kinds of concrete under the same load is also one of the important conditions for judging the strength of concrete.

4.1. Comparison of Compressive Strength of Concrete Cubes

The model is built in Abaqus software. The collected concrete constitutive model parameters are input into Excel to calculate the material property values, and the calculated material property values of C50 ordinary concrete and C50 steel fiber concrete are input into Abaqus software. The two types are divided by a rectangular grid with a side length size of 25. The lower part of the model is completely fixed, and the same load is applied to the upper part.

The extrusion subjected to different degrees of force due to different material properties is shown in Fig. 2. It is obvious from the figure that the extrusion degree of each module of C50 steel fiber concrete is significantly less than that of C50 ordinary concrete. The bottom of C50 ordinary concrete is the most squeezed. With the increase in concrete strength, the distribution of the extrusion degree has no obvious change, but the extrusion degree at the bottom becomes smaller. When the same module is selected from the model, it can be seen that the output value of C50 ordinary concrete is -0. 1789 to 0. 04715, while that of C50 steel fiber concrete is -0. 3115 to 0. 01332 under the same load. It is not difficult to see that the strength of C50 steel fiber concrete is greater than that of C50 ordinary concrete.

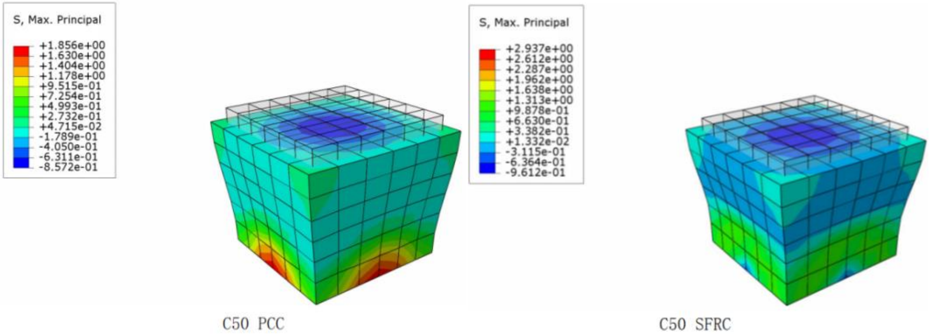

Fig. 2 Extrusion model of ordinary concrete and steel fiber concrete

Fig. 3 shows the distribution of the internal extrusion degree of concrete. It can be seen from the figure that the output value of the part with the maximum extrusion degree of C50 ordinary concrete is 1. 856. However, C50 steel fiber concrete does not have the maximum extrusion position under the same load. According to the numerical table on the left side of C50 steel fiber concrete, it can be seen that its maximum extrusion output value is 2. 937. It also shows that the extrusion degree of C50 steel fiber concrete is less than that of C50 ordinary concrete.

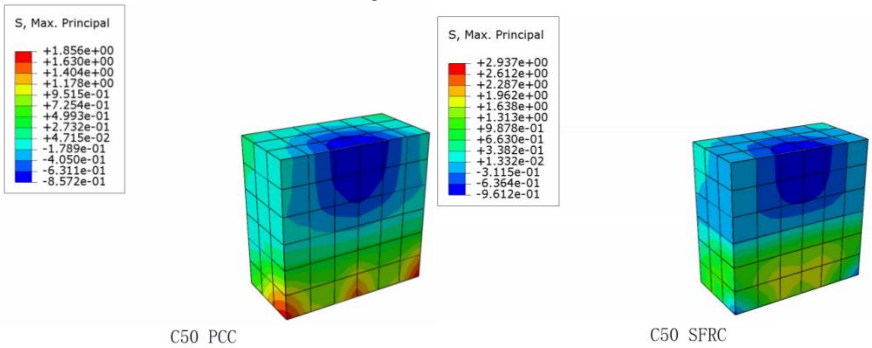

Fig. 3 Internal extrusion model of ordinary concrete and steel fiber concrete

Select the special position points in Fig. 3 to output the stress and strain relationship. The stress-strain curves of two kinds of concrete are obtained in Fig. 4. The stress-strain relationship is similar to the calculated concrete constitutive model, which proves that the output value is similar to the experimental value. It can be seen from the figure that the elastic modulus (stress ratio strain) of C50 ordinary concrete is less than that of C50 steel fiber concrete. It shows that the deformation resistance of C50 steel fiber concrete is stronger than that of C50 ordinary concrete. After applying the same load, the strain of C50 ordinary concrete reaches 0. 005 and tends to change horizontally, and the final strain is 0. 0175. The strain of C50 steel fiber reinforced concrete tends to change horizontally after reaching 0. 004, and the final strain is 0. 0141. The results show that the strength of concrete is improved after adding steel fiber. The data show that the extrusion degree of C50 steel fiber concrete is significantly lower than that of ordinary concrete, and its strength improvement is reflected in higher bearing capacity.

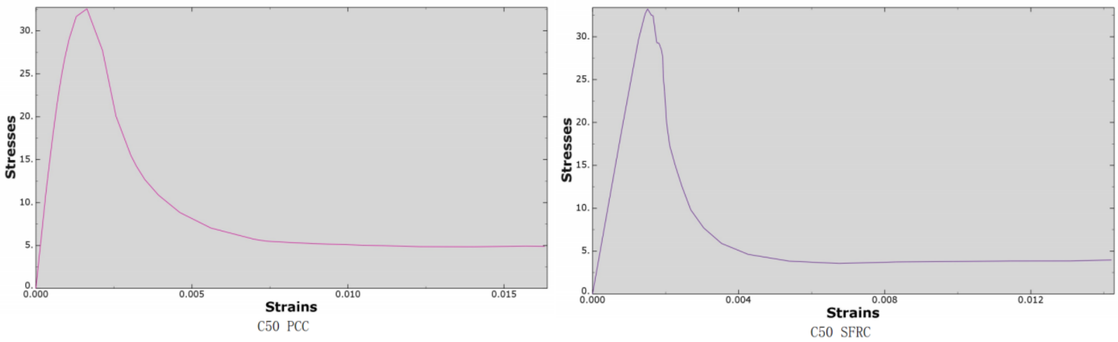

Fig. 4 Stress-strain curves of ordinary concrete and steel fiber concrete

4.2. Comparison of Compressive Strength of Concrete Axis

The prismatic model was built in Abaqus software, and the concrete column was simulated to be fixed with steel plates, as shown in Fig.5, and loads were applied on the steel plates. The material parameters calculated by the cube compressive strength experiment are edited into it. The two types of rectangular grids with a side length size of 18 are selected for division. The other steps are the same.

The experimental results show that the middle of the model has the highest degree of extrusion. In ordinary concrete, the maximum damage value is 0. 2954. The maximum damage value of steel fiber concrete is only 0. 05329. The analysis shows that the maximum damage value of C50 concrete is about 0. 19 times that of ordinary concrete after adding steel fiber, and the strength is higher than that of ordinary concrete. The damage value of C50 common concrete ranges from 0. 214 to 0. 2954. The damage value of C50 steel fiber concrete ranges from 0. 008727 to 0. 05329, which is much smaller than that of C50 ordinary concrete.

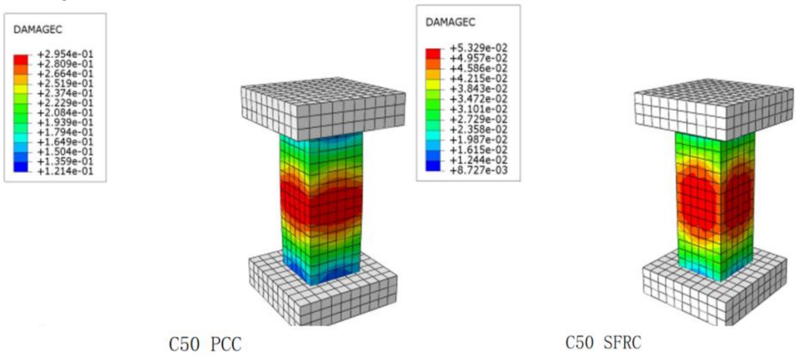

Fig. 5 Axial compressive strength model of ordinary concrete and steel fiber reinforced concrete

Fig. 6 reflects the relationship between concrete force and displacement. It can be seen from the figure that when C50 ordinary concrete is subjected to a force greater than 17KN, the slope of force and displacement gradually decreases, while when C50 steel fiber concrete is subjected to a force greater than 30KN, the slope of force and displacement will gradually decrease. It shows that the change of displacement of C50 steel fiber reinforced concrete is smaller than that of C50 ordinary concrete, and then proves that C50 steel fiber reinforced concrete is stronger than C50 ordinary concrete. The data show that the extrusion degree of C50 steel fiber reinforced concrete is lower than that of ordinary concrete, and its strength improvement is reflected in smaller shape variables.

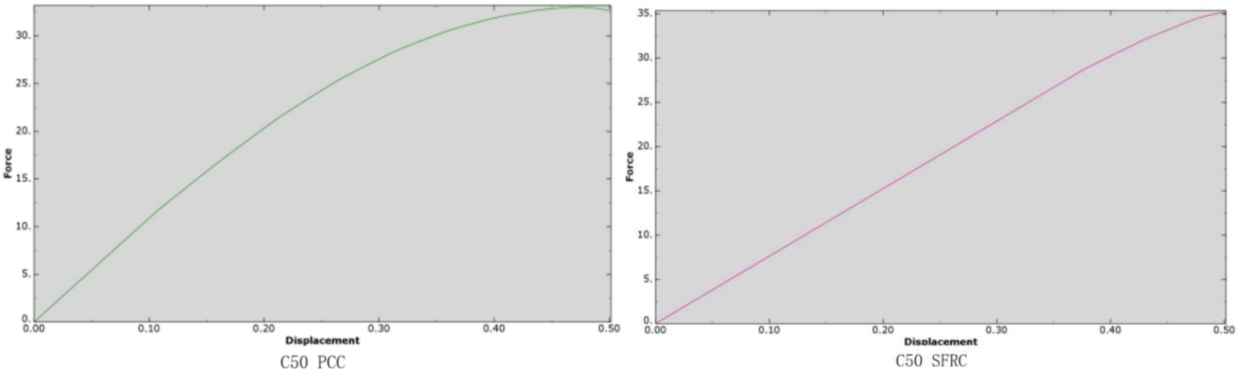

Fig. 6 Force-displacement curves of ordinary concrete and steel fiber concrete

5. Experimental Discussion

5.1. Experimental limitation Analysis

In the experiment of compressive strength of concrete cube, the cuboid grid with a side length of 25 is selected to divide the experimental model after loading. If the grid division is properly reduced to make the loading model more detailed. The model could not be loaded due to errors in the finite element software analysis of the data.

The experimental object selected in the compressive test of the concrete axis is a non-standard specimen, and the bottom side length is 100mm square. Instead of choosing a standard specimen, the bottom side length is 150mm square. The reason is that when the standard test specimen is selected, due to the limited calculated data, there is an error when the calculated data is entered into the finite element software for analysis.

5.2. Cause Analysis of Experimental Error

Error sources mainly include the following three aspects: First of all, the limited calculation data and mesh division may lead to the failure to fully display the stress status of some C50 steel fiber reinforced concrete modules. Secondly, the selection of non-standard specimens limits the universality of experimental results. Finally, the simulation accuracy of the finite element software is still limited to the accurate expression of the damage degree of the upper and lower parts of C50 steel fiber reinforced concrete.

6. Conclusion

This paper takes C50 ordinary concrete and C50 steel fiber concrete as examples. The experimental model is constructed, and the compressive strength of the concrete cube and the compressive strength of the concrete axis are tested. In the cube compressive test, the maximum compressive position of C50 steel fiber concrete does not appear in the compressive model, while the maximum compressive position of C50 ordinary concrete appears. In the axial compressive strength test, the displacement change of C50 steel fiber reinforced concrete is much smaller than that of C50 ordinary concrete. It shows that the compressive strength and deformation resistance of concrete is enhanced after the addition of steel fiber. Compared with ordinary concrete, concrete with steel fiber admixture has the advantages of mechanical properties and safety properties compared with concrete with the same strength grade.

Due to the occurrence of errors. In the following experiments, more effective concrete constitutive model data and more effective constitutive model calculation results are sought. To reduce the experimental error.

In future research, more constitutive models of green concrete will be collected. The corresponding material parameters are calculated and input into the model analysis software. Compare and analyze the safety of other green concrete. Such as carbon fiber concrete, bamboo fiber concrete, fiber recycled concrete, and so on. So that more green concrete can be put into use in future construction projects. Before this, summarize and analyze more safety performance data of green concrete. It is helpful to provide corresponding suggestions and assistance in the selection of materials for building construction.

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