Experimental research on mechanical properties and elastic modulus of glass fiber reinforced concrete

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Abstract. By adding ordinary glass fiber and alkali resistant glass fiber into concrete, the development of axial compressive strength, axial tensile strength and elastic modulus of concrete are studied. The results show that with the increase of glass fiber, the axial compressive strength increases first and then decreases; the axial tensile strength increases; the elastic modulus decreases. The results show that glass fiber can improve the strength of concrete, and reduce the elastic modulus.

Keywords: glass fiber; compressive strength; tensile strength; elastic modulus.

1. Introduction

Concrete is widely used in structures, which has high compressive strength and good fire resistance, but its tensile strength is poo and it is prone to brittle failure.Therefore, many scholars try to add fiber into concrete to improve its shortcomings.In Reference , glass fiber with volume ratio of 0.5%~3% was added into concrete, and it was found that the compressive strength and tensile strength of concrete were improved.In literature , steel fiber,polypropylene fiber,nano- SiO2 were added into concrete, and it was found that the compressive strength and splitting tensile strength of concrete were improved.In literature ,it is found that appropriate amount of SiO2 can improve the compressive strength and elastic modulus of concrete.In literature , it is found that glass fiber can improve the compressive strength, splitting tensile strength and flexural strength of concrete.In literature,it is found that steel fiber can improve the tensile strength. In literature , polypropylene fiber was added into high-strength concrete, and it was found that splitting tensile strength could be improved. In order to study the influence of glass fiber on the mechanical properties of concrete, ordinary glass fiber and alkali resistant glass fiber are added into concrete to study the development of axial compressive strength, axial tensile strength and elastic modulus.

2. Test scheme and results

2.1 Test scheme

The concrete is divided into two groups, the mix proportion is shown in Table.1, and the design strength is C50. The first group incorporated ordinary glass fibers into concrete, the dosage is 0 kg/m3, 2 kg/m3, 4 kg/m3, 6 kg/m3, 8 kg/m3, 10 kg/m3, 12 kg/m3 respectively.The second group incorporated alkali-resistant glass fibers into concrete, the dosage is the same with the first group.The tests of axial compressive strength, axial tensile strength and elastic modulus of the two groups of concrete were carried out.The specimens were put into the standard curing room with temperature 20±2℃ and relative humidity of more than 95% for 28 days.

Table.1 Concrete mix proportion kg / m3

Cement	Water	Sand	Stone	Fly ash	Water-reducing agent	Mineral powder
350	170	622	1096	35	7.0	90

The main parameters of glass fiber and specimens are shown in Table 2 and Table 3.

Table.2 Main parameters of fiber

	Length /mm	Diameter /um	Diameter density / g/cm^3	tensile strength / MPa

Ordinary glass fiber	20~30	14	2.70	1920
Alkali-resistant glass fiber	20~30	18	2.74	2140

Table.3 Main parameters of specimens

Mechanical property	Size	Number
Axial compressive strength	150mm×150mm×300mm	39
Axial Tensile strength	100mm×100mm×550mm	39
Elastic modulus	150mm×150mm×300mm	39

2.2 Test results

2.2.1 Test results of axial compressive strength of glass fiber reinforced concrete

Fig 1 shows the development of axial compressive strength, which first increases and then decreases with the increase of the content of the glass fiber.When the ordinary glass fiber content is 6kg/m3, the axial compressive strength reaches the maximum value, which is 16.95% higher than that of ordinary concrete. When the alkali resistant glass fiber content is 8kg/m3, the axial compressive strength reaches the maximum value, which is 21.69% higher than that of ordinary concrete. The reason is that glass fiber is evenly distributed in the concrete, which better fills the internal voids of concrete and improves the strength of concrete. When the glass fiber content is too much, the glass fiber distribution is uneven and the concrete strength decreases. With the same glass fiber content, the strength of ordinary glass fiber reinforced concrete is lower than that of alkali-resistant glass fiber reinforced concrete. The reason is that cement alkali corrosion ordinary glass fiber, make the glass fiber brittle, the toughness of the concrete becomes worse, alkali resistant glass fiber reinforced concrete overcome this shortcoming.

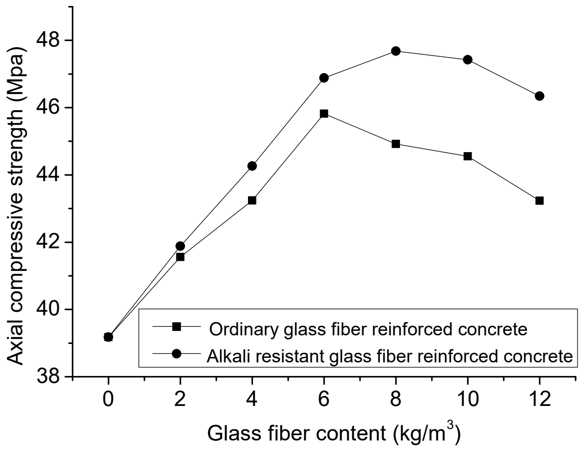

Fig. 1 Development of axial compressive strength of glass fiber reinforced concrete

2.2.2 Test results of axial tensile strength of glass fiber reinforced concrete

Fig. 2 shows the development of the axial tensile strength of glass fiber reinforced concrete. With the increase of glass fiber content, the axial tensile strength of concrete shows an increasing trend, and the strength of alkali-resistant glass fiber reinforced concrete is greater than that of ordinary glass fiber reinforced concrete.When the ordinary glass fiber content is 12kg/m3, the axial tensile strength is 38.07% higher than that of ordinary concrete. When the alkali resistant glass fiber content is 12kg/m3, the axial tensile strength is 52.84% higher than that of ordinary concrete. The reason is that the fibers are distributed in the concrete in a disorderly manner, forming a three-dimensional network system, improving the bond between the fibers and the concrete, and increasing the axial tensile strength.

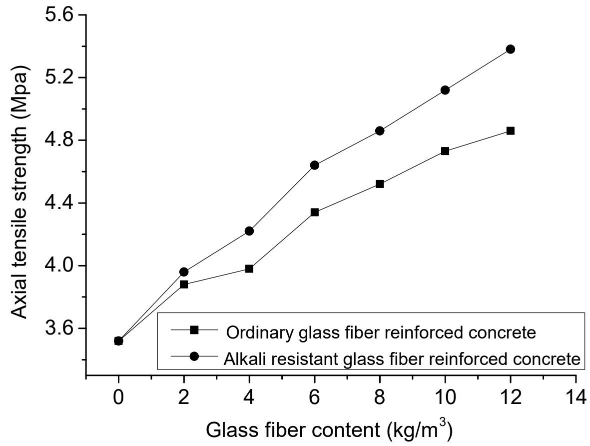

Fig. 2 Development of axial tensile strength of glass fiber reinforced concrete

2.2.3 Test results of elastic modulus of glass fiber reinforced concrete

Fig. 3 shows the development of elastic modulus of glass fiber reinforced concrete. With the increase of glass fiber content, the elastic modulus of concrete decreases, and the elastic modulus of ordinary glass fiber reinforced concrete is greater than that of alkali-resistant glass fiber reinforced concrete. When the ordinary glass fiber content is 12kg/m3, the elastic modulus is 23.67% lower than that of ordinary concrete. When the alkali resistant glass fiber content is 12kg/m3, the elastic modulus is 26.08% lower than that of ordinary concrete. The reason is that glass fiber has small cross-sectional area, high tensile strength and good elasticity.When glass fibers are added to the concrete, the elastic properties of concrete are improved, while the elastic modulus is reduced.

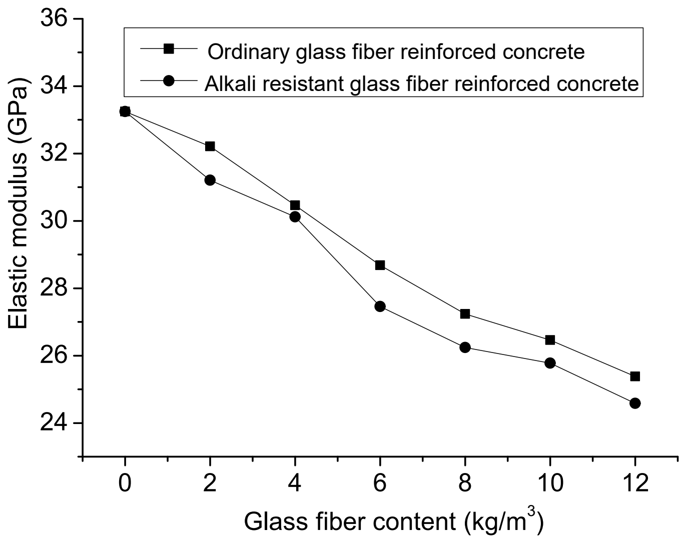

Fig. 3 Development of elastic modulus of glass fiber reinforced concrete

2.2.4 Test results of tension and compression ratio of glass fiber reinforced concrete

The development of tension and compression ratio (ratio of axial tensile strength to axial compressive strength) of glass fiber reinforced concrete is shown in Fig. 4,which increases with the increase of glass fiber. When the glass fiber content is 12kg/m3, the tension and compression ratio of ordinary glass fiber reinforced concrete is increased by 20.09%, and the alkali-resistant glass fiber reinforced concrete is increased by 22.02%, which indicate that glass fiber can improve the plasticity and toughness of concrete, and improve the shortcomings of low tensile strength. The tension and compression ratio of ordinary glass fiber reinforced concrete is smaller than alkali-resistant glass fiber reinforced concrete, indicating that ordinary glass fiber has slightly worse improvement on the tensile and cracking resistance of concrete.

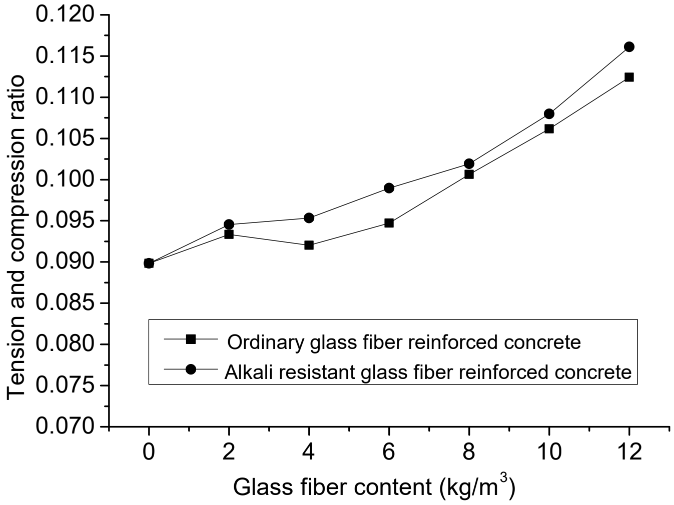

Fig. 4 The development of tension and compression ratio of glass fiber reinforced concrete

3. Calculation model of mechanical properties and elastic modulus

The calculation model of mechanical properties and elastic modulus of glass fiber reinforced concrete obtained by fitting the test data is shown in Equation (1), (2) , (3).

$$f_c(m_s) = (\mathrm{A} \cdot m_s + \mathrm{B}) \cdot f_c(0) \qquad (1)$$

$$f_{ts}(m_s) = (\mathrm{A} \cdot m_s + \mathrm{B}) \cdot f_{ts}(0) \qquad (2)$$

$$E_c(m_s) = (\mathrm{A} \cdot m_s + \mathrm{B}) \cdot E_c(0) \qquad (3)$$

In the formula, $f_c(m_s)$ is the axial compressive strength of glass fiber with the content of m_s; $f_c(0)$ is the axial compressive strength when the content of glass fiber is 0.;$f_{ts}(m_s)$ is the axial tensile strength of glass fiber with the content of m_s; $f_{ts}(0)$ is the axial tensile strength when the content of glass fiber is 0;$E_c(m_s)$ is the elastic modulus of concrete when the content glass fiber is m_s; $E_c(0)$ is the elastic modulus when the content of glass fiber is 0; m_s is the mass of glass fiber in 1m3 concrete.Parameters A,B and correlation coefficient R2 of the calculation model are shown in Table 4.

Table.4 Main parameters of calculation model of mechanical properties and elastic modulus

Mechanical properties	Kind of glass fiber	A	B	R^2
Axial compressive strength	Ordinary glass fiber	0.02757	1.00077	0.99118
	Alkali-resistant glass fiber	0.02808	1.01011	0.967
Axial tensile strength	Ordinary glass fiber	0.03176	1.02009	0.97834
	Alkali-resistant glass fiber	0.04332	1.02658	0.98724
Elastic modulus	Ordinary glass fiber	-0.02059	0.99861	0.98382
	Alkali-resistant glass fiber	-0.02189	0.98476	0.95946

The comparison between experimental and fitting values of axial tensile strength is shown in Fig. 4, Fig. 5 and Fig. 6,there is a good agreement between them.

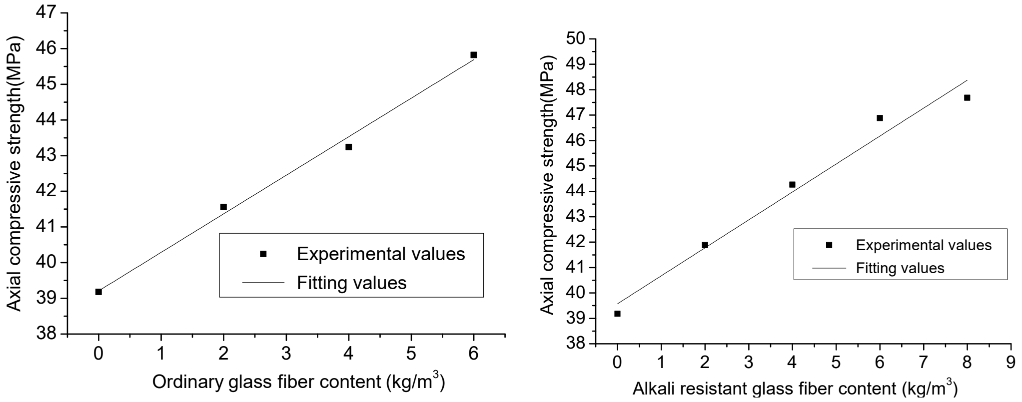

Fig. 4 Comparison of experimental values and fitting values of axial compressive strength

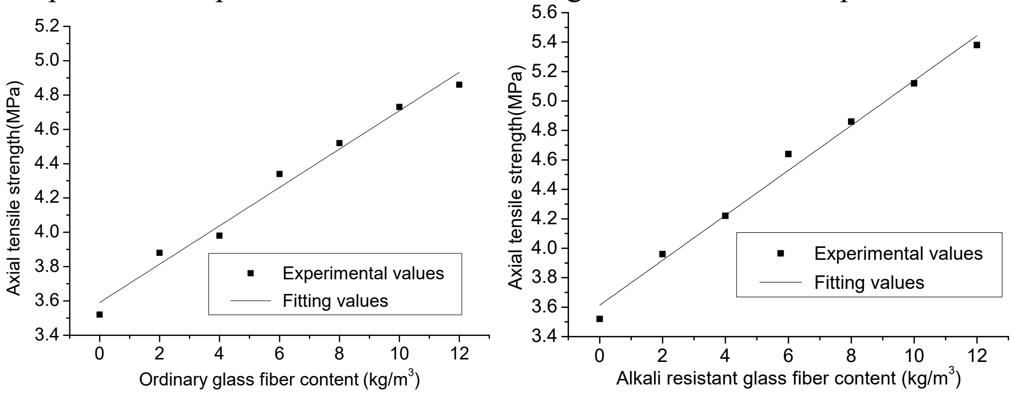

Fig. 5 Comparison of experimental values and fitting values of axial tensile strength

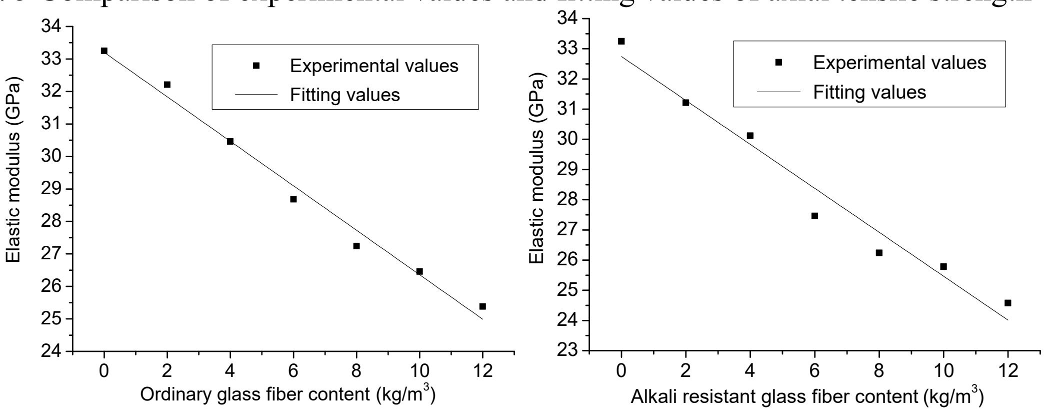

Fig. 6 Comparison of experimental values and fitting values of elastic modulus

Relationship model between axial compressive strength and axial tensile strength

The calculation model of the relationship model between axial compressive strength and axial tensile strength of glass fiber reinforced concrete obtained by fitting the test data is shown in Equation (4)., and the relationship between the two is approximately linear.

$$f_{ts}(m_s) = \mathrm{A} \cdot f_c(m_s) \tag{4}$$

In the formula, $\mathrm{f_{ts}(m_s)}$ is the axial tensile strength of concrete when the content of glass fiber is $\mathrm{m_s}$; $\mathrm{m_s}$ is the mass of glass fiber in 1m3;concrete. $\mathrm{f_c(m_s)}$ is the axial compressive strength of concrete when the content of glass fiber is $\mathrm{m_s}$. Parameters A and correlation coefficient R2 of the ordinary glass fiber reinforced concrete are 0.099267 and 0.99822,while the alkali-resistant glass fiber reinforced concrete are 0.09669 and 0.99024.

The comparison between experimental and fitting values is shown in Fig. 7, there is a good agreement between them.

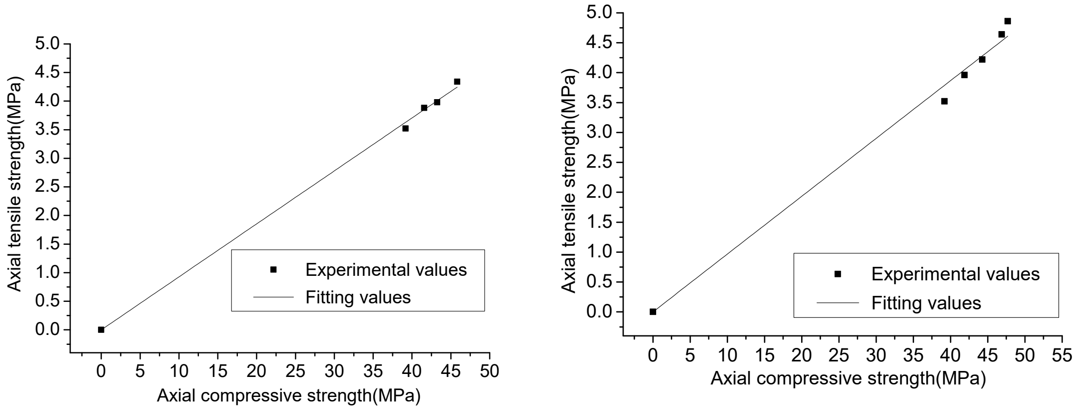

Fig. 7 Comparison of experimental values and fitting values of relationship model between axial compressive strength and axial tensile strength

4. Conclusion

With the increase of glass fiber, the axial compressive strength of concrete increases first and then decreases, and the strength of alkali-resistant glass fiber reinforced concrete is greater than that of ordinary glass fiber reinforced concrete. With the increase of glass fiber content, the axial tensile strength of concrete shows an increasing trend, and the alkali-resistant glass fiber significantly improves the strength of concrete than ordinary glass fiber. With the increase of glass fiber content, the elastic modulus of concrete showed a decreasing trend, and the alkali-resistant glass fiber significantly reduced the elastic modulus of concrete than that of ordinary glass fiber reinforced concrete. According to the test results, it is recommended to add 6kg/m3 of ordinary glass fiber and 8kg/m3 of alkali-resistant glass fiber into concrete.

5. Acknowledgement

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