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# Mechanical Properties of Steel Fiber Reinforced all Lightweight Aggregate Concrete

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**Abstract.** In order to study the basic mechanical properties and failure characteristics of alllightweight aggregateconcrete with different volume of steel fiber (0%, 1%, 2%),shale ceramsite is used as light coarse aggregate. The shale sand is made of light fine aggregate and mixed with different volume of steel fiber, and the mix proportion design of all lightweight aggregate concrete is carried out. The cubic compressive strength, axial compressive strength, flexural strength, splitting strength and modulus of elasticity of steel fiber all lightweight aggregate concrete were studied.Test results show that the incorporation of steel fiber can restrict the cracking of concrete,improve crack resistance; at the same time, it shows good plastic deformation ability and failure morphology. It lays a theoretical foundation for further research on the application of all lightweight aggregate concrete in structural systems.

## 1. Introduction

As a branch of lightweight aggregate concrete,all lightweight aggregate concrete is lightweight aggregate concrete made of lightweight coarse aggregate, light fine aggregate, cementitious material and cement and water[1],bulk density below 1700Kg/m$^3$.All lightweight aggregate concrete is a lightweight, energy-saving and environment-friendly building material,The utility model has the advantages of good structural performance, good seismic performance, heat insulation, good durability, etc.But there are some disadvantages, such as low tensile strength and poor toughness.Steel fiber is a kind of good toughness reinforced material, and has been paid much attention by many scholars[2].At present, a great deal of research has been done on fiber reinforced concrete materials,it is found that the fiber concrete member has good crack resistance, good deform ability and good energy absorption capacity,but the research on the steel fiber concrete is still very weak.With the application of fiber concrete in construction, transportation, military and other fields,it is urgent to make a thorough study of all kinds of steel fiber lightweight concrete and provide a theoretical basis

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for the rapid application of engineering structural members.

## 2. Experimental design

*2.1 .Main raw material*

The cement is made of ordinary 42.5 Portland cement produced by Jilin Yatai India Cements Limited;light coarse aggregate is made of shale ceramsite from light building materials factory of Tianjin Wu Tong District,the particle size is 5~30mm;Light fine aggregate used Jilin Nong'an Yixing wall materials Co. Ltd production of shale pottery,The particle size is 3~4mm;The admixture has fly ash and ordinary water reducing agent.The main properties of ceramsite and earthenware sand are shown in Table 1.Steel fiber use shear wave type steel fiber produced by Liaoning Anshan Corbett limited, The main parameters are shown in table 2.

**Table 1 .** main properties of ceramsite and earthenware sand

| Type | Sieve analysis (mm) | Bulk density (kg/m³) | Apparent density (kg/m³) | Void fraction (%) | Water absorption (%) | Cylinder pressure strength (Mpa) |
|---|---|---|---|---|---|---|
| Shale ceramsite | 5-30 | 765 | 820 | 43 | 5.6 | 7.2 |
| Shale ceramic sand | 3-4 | 480 | 770 | 38 | 11.2 | 3.6 |

**Table 2.** main parameters of steel fiber

| Name | Length(mm) | Diameter(mm) | Aspect ratio | Tensile strength(Mpa) | Modulus of elasticity(Mpa) |
|---|---|---|---|---|---|
| Shear wave type steel fiber | 30 | 0.6 | 50 | ≥770 | 200000 |

*2.2. Mixture ratio design*

According to JGJ51-2002 *Technical specification for lightweight aggregate concrete,*mix proportion design of lightweight concrete is carried out by using loose volume method.Through reasonable mix design,give full play to light aggregate lightweight features,at the same time, adding different volume of steel fiber can improve the toughness and shear resistance of all lightweight concrete.Steel fiber all lightweight aggregate concrete mix proportion as shown in Table 3.

**Table 3.** Steel fiber all lightweight aggregate concrete mix proportion

| Number | Steel fiber volume fraction | Cement/kg | Shale ceramsite/kg | Shale ceramic sand/kg | Fly ash/kg | Water reducer/% | W/C |
|---|---|---|---|---|---|---|---|
| G0 | 0% | 100 | 100 | 60 | 10 | 0.75 | 0.4 |
| G1 | 1% | 110 | 100 | 60 | 10 | 0.75 | 0.4 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| G2 | 2% | 120 | 100 | 60 | 10 | 0.75 | 0.4 |

## 3.Experimental design

According to *Standard for test method of mechanical properties on ordinary concrete* to make standard test blocks,it is used to study the basic mechanical properties of steel fiber reinforced concrete.The design plan of each block is shown in Table 4.

**Table 4.** design schemes of steel fiber volume fraction (0%, 1% and 2%)

| Shape of test block | Test block size | Number | Parameter index |
|---|---|---|---|
| cube | 150mm×150mm×150mm | 6×3 | standard cube compressive strength,Splitting strength |
| Prism | 150mm×150mm×300mm | 6×3 | Axial compressive strength,Modulus of elasticity |
| Cuboid | 150mm×150mm×550mm | 3×3 | Rupture strength |

## 4. Experimental study on basic mechanical properties

*4.1 .Cube compressive strength and axial compressive strength*

According to existing standard for test methods and standards,the cubic compressive strength and axial compressive strength of steel fiber and lightweight concrete were tested and measured.The results are shown in Table 5.

The initial stage of loading,the G0 series test block has a crisp splitting sound,no damage on the surface of the test block.When loading to approximately 50% ultimate load,a small amount of tiny cracks appear on the surface of the specimen.When loading to approximately 80% ultimate load,the number of test block surface crack increase, accelerate the development and hear concrete damage sounds.After reaching the limit load,the surface of the test block developed a main fissure from the original crack,at the same time will see the cracks in steel fiber pull-out from the distribution of clutter in concrete,the cracks continue to crack along the direction of the steel fiber until the specimen is broken.The G2 series is similar to the G1 series,the failure process of the specimen is shown in Figure 1.Judging from the test process and failure phenomenon, G0 is considered as brittle fracture,The incorporation of G1 and G2 steel fibers can obviously improve the crack resistance and energy absorption ability of the component.


Figure 1. cube compressive strength and axial compressive strength test

**Table 5.** cube compressive strength and axial compressive strength of test block

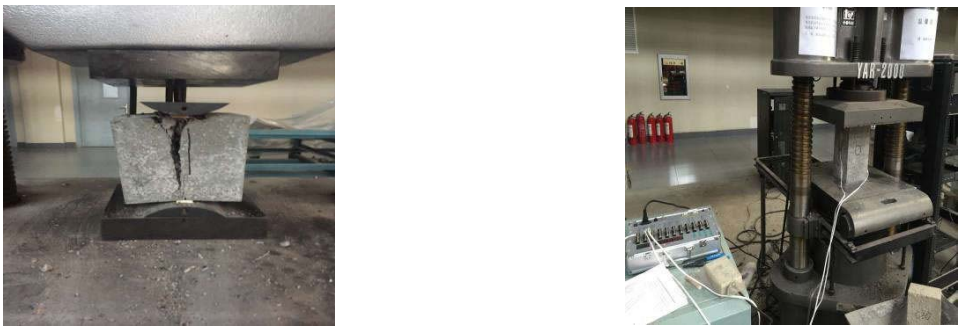
| Test name | G0cube compressive strength/ MP | G1cube compressive strength/ MP | G1cube compressive strength/ MP | G0Axial compressive strength/MP | G1Axial compressive strength/MP | G2Axial compressive strength/MP |
|---|---|---|---|---|---|---|
| 1 | 35.24 | 38.78 | 45.91 | 40.43 | 43.36 | 43.08 |
| 2 | 37.69 | 38.91 | 44.42 | 40.39 | 41.96 | 45.51 |
| 3 | 36.49 | 40.88 | 47.20 | 40.73 | 43.12 | 44.24 |
| average value | 36.47 | 39.52 | 45.84 | 40.52 | 42.81 | 44.28 |

*4.2 .Elastic modulus and splitting strength*

The magnitude of splitting tensile strength, the occurrence and development of cracks in the reaction material under Splitting Tension.The test results are shown in Table 6, and the damage pattern is shown in Figure 2 (a).Modulus of elasticity is an index to measure the degree of difficulty of elastic deformation of materials,The greater the value, the smaller the elastic deformation under a certain stress.According to the existing standard of test method, the elastic modulus of steel fiber and lightweight concrete is tested and calculated.The test results are shown in Table 7, and the damage pattern is shown in Figure 2 (b).The experimental data show that the elastic modulus of all lightweight concrete can be improved by adding steel fiber under the same loading condition,it shows that under certain stress conditions, the total lightweight concrete with volume fraction of 1% and 2% of steel fiber is more prone to plastic deformation than whole lightweight concrete without steel fiber.

**Table 6.** elastic modulus and splitting strength of test block

| Test name | G0-Modulus of elasticity/MP | G1-Modulus of elasticity/MP | G2-Modulus of elasticity/MP | G0-Splitting strength/MP | G1-Splitting strength/MP | G2-Splitting strength/MP |
|---|---|---|---|---|---|---|
| 1 | $1.94\times10^4$ | $2.25\times10^4$ | $2.33\times10^4$ | 3.42 | 6.88 | 7.95 |
| 2 | $1.89\times10^4$ | $2.31\times10^4$ | $2.28\times10^4$ | 3.67 | 6.65 | 7.58 |
| 3 | $2.04\times10^4$ | $2.18\times10^4$ | $2.39\times10^4$ | 3.76 | 7.23 | 7.64 |
| average value | $1.96\times10^4$ | $2.25\times10^4$ | $2.33\times10^4$ | 3.62 | 6.92 | 7.72 |



(a)Splitting failure (b)Elastic modulus test

Figure 2.test of elastic modulus and splitting strength of test block

## 5.Conclusion

(1) The test results show that the density of lightweight concrete is lower than that of ordinary concrete,strength did not decrease,at the same time, it has good plastic deformation ability and failure morphology.

(2) Through cube compression test and axial compression test, we can see that,the compression failure of all lightweight concrete without steel fiber starts from the tension crack of cement mortar,Then, run through the aggregate,fracture of lightweight aggregate in Failure surface.

(3) The compressive damage of all lightweight concrete mixed with steel fiber starts from the tension crack of cement mortar and then develops with the direction of steel fiber,the crack number is small, and the failure surface can be seen randomly distributed in the steel fiber,the section is not smooth and the strength is obviously higher than that of all lightweight concrete without steel fiber,it shows that steel fiber can effectively limit the amount and development of cracks, and has good crack resistance and energy absorption.

(4) Through the elastic modulus test, we can see that,illustrates under certain stress conditions,all lightweight concrete mixed with steel fiber is more prone to plastic deformation than lightweight concrete without steel fiber.

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