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Research Progress on Mechanical Properties of Steel Fiber Reinforced Alkali-activated Concrete

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Abstract

In this paper, the mechanical properties of steel fiber reinforced alkali-activated cementitious materials are introduced. The results show that the appropriate proportion of long steel fiber and short fiber is better than that of single long steel fiber or short steel fiber to enhance the splitting tensile strength of alkali-activated concrete. This may be because short and long fibers can effectively inhibit the expansion of microcracks and macrocracks, respectively.

Keywords

Slag; fly ash; alkali-activated cementitious material; mechanical properties; research progress.

1. Introduction

Alkali-activated cementitious material is a new type of cementitious material produced by chemical reaction between aluminosilicate raw material (precursor) and alkali activator. According to the different calcium content, the raw materials of alkali-activated cementitious materials can be divided into high calcium aluminosilicate materials (slag, etc.) and low calcium aluminosilicate materials (fly ash, kaolin, etc.). In the 1940s, Purdon conducted extensive research on alkali-activated cementitious materials composed of slag and NaOH solution [1]. In the 1950 s, the Soviet Union developed alkali slag cement and applied this cementing material to industry in the 1960 s. In the late 1970 s, Davidovits studied alkali-activated metakaolin cementitious materials and first proposed the concept of geopolymer [2]. Alkali-activated cementitious material and geopolymer are not exactly the same. Geopolymer is a kind of alkali-activated cementitious material. Compared with ordinary Portland cement concrete, the CO2 produced by the preparation of alkali-activated concrete is reduced by 55 % ~ 75 % [3]. Alkali-activated cementitious materials have the advantages of high strength, good durability and low energy consumption. Therefore, alkali-activated cementitious materials are considered to be an excellent substitute for ordinary Portland cement and have great development prospects in the future.

Domestic and foreign scholars have conducted extensive research on alkali-activated cementitious materials and achieved a lot of results. In order to promote the research and development of alkali-activated cementitious materials, this paper summarizes the research results of steel fiber reinforced alkali-activated cementitious materials.

2. Mechanical Properties of Steel Fiber Reinforced Alkali-Activated Cementitious Materials

Steel fiber is often used in cement concrete due to its high mechanical strength, flexibility and availability. In order to improve the mechanical properties of alkali-activated concrete, adding steel fiber into alkali-activated concrete is an effective method.

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For the way of adding a type of steel fiber to enhance the mechanical properties of alkali-activated concrete, Ganesan et al. [4] studied the effect of different amounts of steel fiber on the mechanical properties of alkali-activated fly ash concrete. The results show that with the increase of steel fiber content, the compressive strength, splitting tensile strength, elastic modulus and bending strength of alkali-activated fly ash concrete gradually increase. Zheng et al. [5] studied the effect of different content of steel fiber on the mechanical properties of alkali-activated slag-fly ash concrete. See table 1. With the increase of fiber content, the compressive strength, splitting tensile strength and prism compressive strength of steel fiber alkali-activated slag-fly ash concrete at each age gradually increase, while the elastic modulus gradually decreases.

Table 1. Splitting tensile strength, cube compressive strength and prism compressive strength of steel fiber alkali-activated slag-fly ash

Fiber content	$f_{sp,28}$		$f_{cu,28}$		$f_{c,28}$		$E_{c,v}$(GPa)
	7 days	28 days	7 days	28 days	7 days	28 days	
0	2.46	3.71	39.1	47.7	38.3	38.3	18.8
38.9	3.01	3.98	40.5	50.1	39.8	39.8	18.5
77.8	3.70	4.47	42.6	52.4	41.6	41.6	18.1
116.7	3.98	4.79	43.5	54.3	42.6	42.6	17.8
155.6	4.58	5.51	45.1	56.4	43.9	43.9	17.2

Yuan et al. [6] studied the effect of different content of steel fiber on the mechanical properties of alkali-activated slag concrete. The results show that with the increase of steel fiber content, the strength, Young 's elastic modulus and Poisson 's ratio of alkali-activated slag concrete increase. Ding and Bai [7] studied the effect of different amounts of steel fiber on the mechanical properties of alkali-activated slag concrete. The results show that the compressive strength and tensile strength of alkali-activated slag concrete increase with the increase of steel fiber content. Rossi et al [8] studied the mechanical properties of alkali-activated slag concrete with different contents and different shapes of steel fibers. The results show that compared with alkali-activated slag concrete without steel fibers, the cubic compressive strength and prism compressive strength of alkali-activated slag concrete with steel fibers are increased. Kim et al. [9] studied the effect of different content of steel fiber on the compressive strength of alkali-activated slag concrete. The results show that the compressive strength of alkali-activated slag concrete can be improved by adding appropriate amount of steel fiber. Bernal et al. [10] studied the effect of different amounts of steel fiber on the mechanical properties of alkali-activated slag concrete. The results showed that the incorporation of steel fiber reduced the compressive strength of alkali-activated slag concrete, while the splitting tensile strength and flexural strength were greatly improved.

For the way of adding long steel fiber and short steel fiber to enhance alkali-activated concrete, El-Hassan and Elkholy [11] studied the mechanical properties of room temperature curing alkali-activated slag-fly ash mixed concrete with different steel fiber hybrid combinations with a volume fraction of 1 %. Four kinds of steel fibers with different lengths, different curvatures and different tensile strengths are used, as shown in Fig. 1. The geometric and physical properties of the four kinds of steel fibers are shown in Table 2. The compressive strength and splitting tensile strength of alkali-activated slag-fly ash concrete are obtained, as shown in Figs. 2 and 3. The results show that compared with short fibers (3DS steel fibers). Long fibers (3DL steel fiber, 4D steel fiber and 5D steel fiber) have better effect on enhancing the compressive strength of alkali-activated slag-fly ash concrete. Under the same steel fiber content, the compressive strength and splitting tensile strength of alkali-activated slag-fly ash reinforced by

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appropriate proportion of hybrid short fiber and long fiber are better than those of single short steel fiber or long steel fiber.

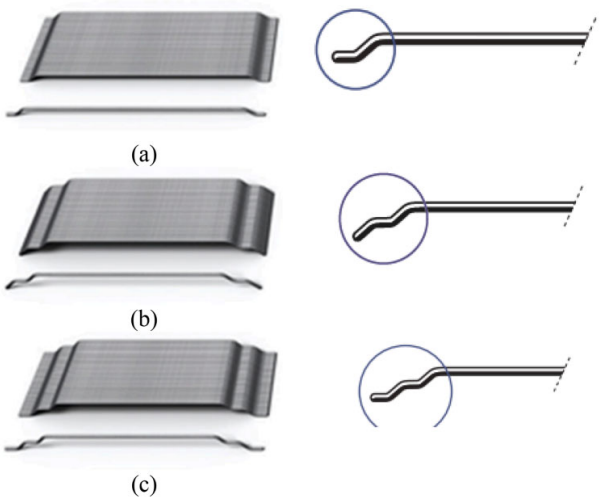

Figure 1. Steel fiber (a) 3DS/3SL (b) 4D (c) 5D

Table 2. Geometric and physical properties of four kinds of steel fibers

Fiber name	d_f (mm)	l_f (mm)	d_f/ l_f	Density (g/cm^3)	f_t (MPa)	E_f (GPa)
3DS	0.55	35	65	7.9	1345	210
3DL	0.90	60	65	7.9	1160	210
4D	0.90	60	65	7.9	1500	210
5D	0.90	60	65	7.9	2300	210

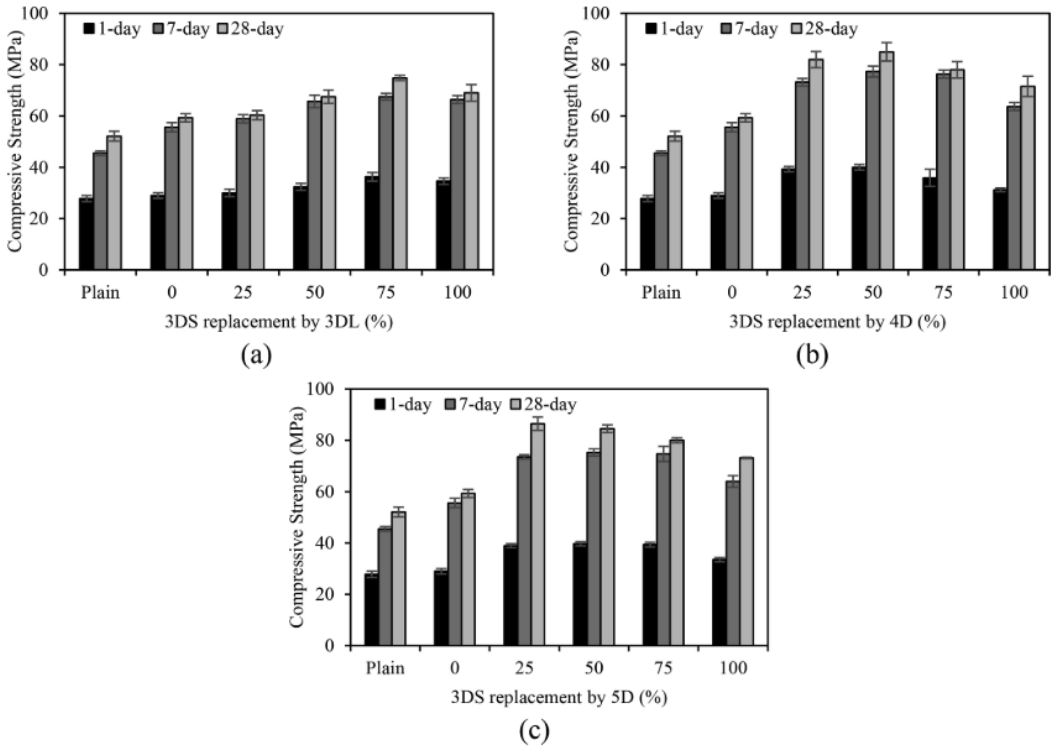

Figure 2. Effect of steel fiber hybrid on compressive strength (a)3DL (b)4D (c)5D

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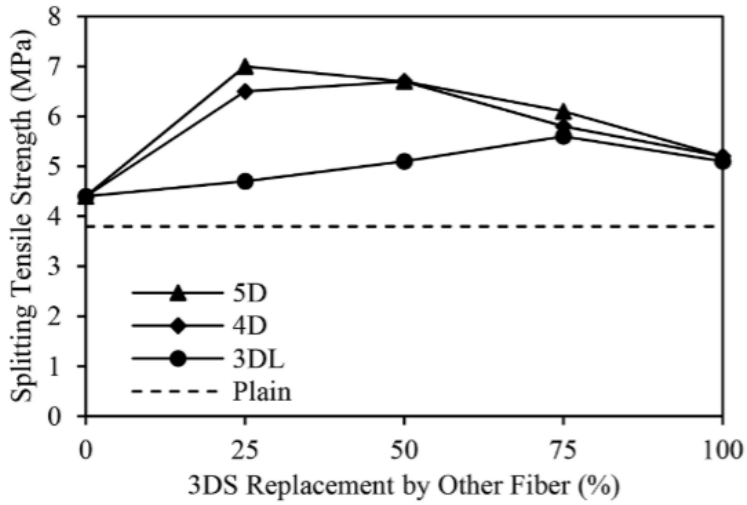

Figure 3. Effect of steel fiber hybrid on splitting tensile strength

Farhan et al. [12] studied the effect of different types of steel fibers on the mechanical properties of alkali-activated slag-fly ash concrete. The results show that the incorporation of fibers improves the compressive strength, splitting tensile strength and flexural strength of alkali-activated slag-fly ash concrete. Under the same steel fiber content, the compressive strength and splitting tensile strength of alkali-activated slag-fly ash reinforced by a proper proportion of hybrid short fibers and long fibers are better than those of single short steel fiber or long steel fiber.

It can be seen that:

(1) Some scholars believe that adding an appropriate amount of steel fiber can improve the compressive strength, tensile strength and flexural strength of alkali-activated concrete. However, some scholars have put forward different views that the incorporation of steel fiber leads to the decrease of compressive strength of alkali-activated concrete and the increase of splitting tensile strength and flexural strength.

(2) The appropriate proportion of long steel fiber and short fiber is better than the single long steel fiber or short steel fiber to enhance the splitting tensile strength of alkali-activated concrete. This may be because the short and long fibers can effectively inhibit the propagation of micro-cracks and macro-cracks, respectively.

3. Conclusions and Prospects

3.1. Conclusions

In this paper, the mechanical properties of steel fiber reinforced alkali-activated cementitious materials are introduced. The following conclusions can be drawn:

(1) Some scholars believe that adding an appropriate amount of steel fiber can improve the compressive strength, tensile strength and flexural strength of alkali-activated concrete. However, some scholars have put forward different views that the incorporation of steel fiber leads to the decrease of compressive strength of alkali-activated concrete and the increase of splitting tensile strength and flexural strength.

(2) Adding appropriate amount of steel fiber can improve the tensile strength of alkali-activated concrete ; the appropriate proportion of long steel fiber and short steel fiber is better than that of single long steel fiber or short steel fiber to enhance the tensile strength of alkali-activated concrete.

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3.2. Prospects

Although scholars at home and abroad have done a lot of research on alkali-activated cementitious materials, there are still some aspects that need further study.

(1) There are many factors affecting the performance of alkali-activated concrete. The popularization and application of alkali-activated concrete need more perfect standard.

(2) The high temperature resistance of alkali-activated slag concrete needs further study.

(3) The shrinkage of alkali-activated slag concrete is larger than that of Portland cement, so it is necessary to further study the shrinkage of alkali-activated slag.

(4) Due to the wide source of precursor materials, the mix design of alkali-activated concrete needs further study.

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