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Properties of Alkali Activated Slag Concrete

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In order to study the effect of fiber and fly ash on the performance of alkali activated slag concrete, the effect of different fiber and fly ash content on the performance and mechanical properties of alkali activated slag concrete is analyzed and compared on the premise of optimizing the cement mixture ratio. The results show that fly ash increases the workability of ordinary concrete, while the addition of fly ash in alkali activated slag concrete reduces the workability of concrete. When the fiber content is 0.9kg/m3 and 1.8kg/m3, the compressive strength of alkali activated slag concrete at 28d is increased by 1.3% and 19.1%, respectively. The fly ash reduces the early compressive strength of the two kinds of concrete and increases the compressive strength after 28d.

1. Introduction

Alkali activated slag concrete has the advantages of simple production process, low energy consumption, excellent physical and mechanical properties and durability. It is a green building material with energy saving and environmental protection (Serdar and Bülent, 2013). It is necessary to carry out relevant research and promote the application, which is in line with the requirements of sustainable development strategy, and is of great significance to resources and environment. However, the composition of alkali activated slag concrete is complex, the early hydration speed is very fast (Yun et al., 2017). The hydration product is complex, the dry shrinkage is big, and it is easy to produce cracks (Wu-Jian et al., 2017). The ratio of tension and compression decreases with the increase of age, and the brittleness of concrete increases, which leads to brittle failure (Jae-Ho et al., 2017) and affects the safety and use of the structure.

Fiber has the function of crack resistance, reinforcing and toughening for ordinary concrete (Musaad et al., 2017), which is often used in concrete to improve its brittleness and improve the tensile strength of concrete (Se-Jin et al., 2015). The effect of synthetic fiber on the mechanical properties of alkali activated slag concrete and ordinary concrete is studied, and some properties of alkali activated slag concrete are obtained. It is expected that the research results can provide some theoretical support for the practical application of alkali activated slag cement and concrete, and promote the rapid development of alkali activated slag concrete.

2. Method

2.1 Raw material

Experimental materials: P.O 52.5 ordinary portland cement (specific surface area 315㎡/kg), powdered ground slag (specific surface area 400㎡/kg), the secondary fly ash discharged from thermal power plant, polypropylene fiber for concrete, sodium silicate, sodium hydroxide.

2.2 Experimental procedure

The specific experimental ratio is shown in table 1. The concreted is prepared according to the experimental scheme shown in table 1. In order to make the fiber distributed evenly and improve the uniformity of the mixture, the 60L laboratory special forced mixer is adopted, and the mixing time is strictly controlled. Sand, stone aggregate, cementitious material (cement, fly ash), fiber and admixture are added in order. The mixture is stirred for 90s, then is stirred for 120s after adding water (sodium hydroxide solution, sodium silicate solution) (Yufeng et al., 2014).

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Table 1: Experimental study of concrete

N	Slag %	Fly ash %	Fiber kg/m^3	Water-cement ratio	Sand rate	Retarder %	N	P.O. %	Fly ash %	Fiber kg/m^3	Water-cement ratio	Sand rate	Retarder %
J1	100	0	0	0.4	0.4	1.5	C1	100	0	0	0.4	0.4	1.2
J2	75	25	0	0.4	0.4	1.5	C2	75	25	0	0.4	0.4	1.2
J3	100	0	0.9	0.4	0.4	1.5	C3	100	0	0.9	0.4	0.4	1.2
J4	100	0	1.8	0.4	0.4	1.5	C4	100	0	1.8	0.4	0.4	1.2
J5	75	25	0.9	0.4	0.4	1.5	C5	75	25	0.9	0.4	0.4	1.2

2.3 Sample detection method

Slump experiment on fiber alkali slag concrete: Unloading the mixture and immediately testing the slump and expansion of concrete (Yanqing et al., 2016), measuring the concrete workability of each group.
Compressive strength test of fiber alkali activated slag concrete refer to GB/T50081-2002 "Standard of test method for mechanical properties of ordinary concrete". The size of the cube specimen is 100mm x 100mm x 100mm. The compressive strength of concrete specimens is the test value multiplied by the reduction factor 0.9.
Flexural strength of fiber alkali activated slag concrete refers to GB/T50081-2002 "Standard of test method for mechanical properties of ordinary concrete". The size of cuboid specimen is 100mm×100mm×400mm. The flexural strength of concrete specimens is the test value multiplied by the reduction factor 0.82.

3. Results

3.1 Working performance

The working performance of concrete in each group is shown in table 2:

Table 2: Performance of different concrete

N	Slag %	Fly ash %	Fiber kg/m^3	Slump degree cm	Degree of expansion cm	N	P.O. %	Fly ash %	Fiber kg/m^3	Slump degree cm	Degree of expansion cm
J1	100	0	0	25	60	C1	100	0	0	22	64
J2	75	25	0	23	55	C2	75	25	0	23	66
J3	100	0	0.9	24	50	C3	100	0	0.9	21.5	50
J4	100	0	1.8	21	40	C4	100	0	1.8	20	35
J5	75	25	0.9	21	40	C5	75	25	0.9	22	58

As shown in the table, alkali activated slag concrete and ordinary concrete all have good fluidity. When the special composite retarder is added into alkali slag concrete, the setting time of alkali activated slag concrete is reduced, and it can be used instead of water reducing agent (Jingjing, et al., 2016). This narrows the water consumption between alkali activated slag concrete and ordinary concrete similar. The effect of fiber and fly ash on the working performance of two kinds of concrete is shown in figure 1 and figure 2.

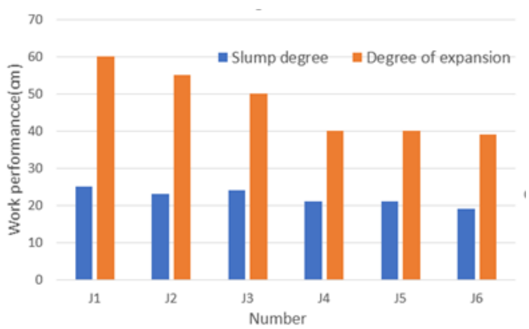

Figure 1: Slump and expansion of concrete with different alkali slag

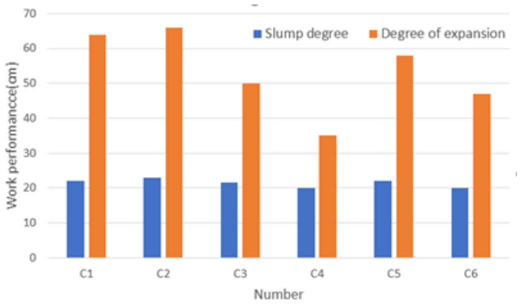

Figure 2: Slump and expansibility of different ordinary concrete

From table 2, figure 1 and figure 2, it is known that the slump of soda ash slag concrete is larger and the expansion degree is smaller under the condition of the same mixing ratio. After adding fiber and fly ash into two kinds of concrete, the working performance of concrete has changed differently. The specific function analysis is as follows:

After adding fly ash and fiber with different content into soda ash slag, the workability is reduced in different degrees with the increase of fiber content. When the fiber and fly ash are mixed, the workability is further reduced, and the fluidity of alkali activated slag concrete is not improved by mixing (Alaa, 2013).

When fly ash is added to pure ordinary concrete, the slump and expansion degree increase slightly, and the workability of ordinary concrete is improved. After adding different amount of fiber, the slump and the expansion degree decrease, and the workability of concrete also decreases with the increase of the content. The mixing of the two materials has no positive effect on the workability of ordinary concrete (Zhenguo et al., 2017).

It is concluded that the effect of fiber on the workability of two kinds of concrete is basically the same, that is, fiber reduces slump and expansion of two kinds of concrete. The fiber reduces the working performance, and the larger the fiber content is, the greater the decrease of fluidity is. This is because, compared with the sandstone with the same volume, the specific surface area of the fiber is greater, the fiber required for cement paste is relatively more. At the same time, the fiber surface also absorbs more moisture, so that the consistency of the slurry increases and the liquidity decreases (Mohammad and Suriya, 2015).

The effect law of fly ash on two kinds of concrete is also different. First of all, fly ash increases the workability of ordinary concrete, because the fly ash has good surface morphology and regular spherical shape. The "bead effect" is obvious (Ricarda et al., 2017), so the fluidity of the mixture is increased. However, after adding fly ash into alkali activated slag concrete, because the specific surface area of fly ash is larger than that of slag, the water demand is greater, the consistency of mixture is increased (Keeley et al., 2017), and the workability of concrete is reduced.

3.2 Compressive strength analysis of fiber alkali activated slag concrete

The effect of fiber and fly ash on the compressive strength of two kinds of concrete is shown in table 3:

Table 3: Compressive strength and relative strength of concrete at different ages

N	Compressive strength (MPa)					Relative to 28 days of strength (%)				
	1d	3d	7d	28d	90d	1d	3d	7d	28d	90d
J1	30.4	52.4	65.4	69.7	88.7	43.6	75.2	93.8	100.0	127.3
J2	25.6	47.1	65.2	76.5	92.7	33.5	61.6	85.2	100.0	121.2
J3	33.5	53.8	64.5	70.6	87.8	47.5	76.2	91.4	100.0	124.4
J4	30.3	55.4	64.4	83.0	96.3	36.5	66.7	77.6	100.0	116.0
J5	25.2	47.1	66.9	74.4	90.5	33.9	63.3	89.9	100.0	121.6
J6	24.1	42.0	61.1	78.2	92.8	30.8	53.7	78.1	100.0	117.6
C1	8.1	46.2	51.5	62.3	71.1	13.0	74.2	82.7	100.0	114.1
C2	2.0	39.6	48.0	64.1	72.2	3.1	61.8	74.9	100.0	112.6
C3	7.3	48.3	58.7	66.5	69.8	11.0	72.6	88.3	100.0	105.0
C4	12.4	47.1	58.3	68.3	73.9	18.2	69.0	85.4	100.0	108.2

As shown in table 3, the compressive strength of soda slag concrete at each stage are higher than ordinary concrete. Especially at the 1d, the compressive strength of the former is 3-4 times of the latter, and the early strength development rate is obviously faster than ordinary concrete. It has better early strength

characteristics and reaches to 43% of 28d strength at 1d. In addition, it reaches 94% of the 28d strength at 7d. The alkali slag concrete has better strength, and the intensity is still growing rapidly after 90d strength. Compared with the growth rate (27.3%) of 28d compressive strength, the 90d compressive strength is almost two times of the compressive strength growth rate (14.1%) of ordinary concrete.
The effect of synthetic fiber and fly ash on the compressive strength of alkali activated slag concrete is shown in figure 3:

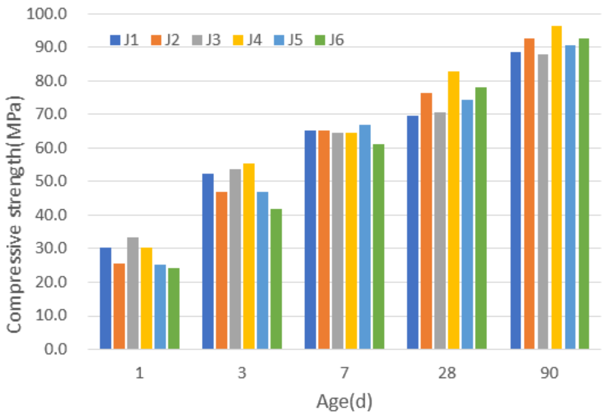

Figure 3: Compressive Strength of Alkali - activated Slag Concrete at Different Ages

As shown in figure 3, the compressive strength is lower than soda slag concrete before adding the fly ash into alkali slag concrete with 7d. The fly ash decreases the strength before 7d and increases the strength after 28d. The compressive strength of 28d and 90d is higher than soda slag concrete. The development speed of each strength also becomes slow. The ductility of late strength is also slightly lower. The above results show that the early activity of fly ash is lower than slag. With the development of hydration process, the activity of fly ash is gradually brought into play. The activity of fly ash at 7d is close to slag, and the activity of fly ash after 28d is obviously higher than slag. The early activity of fly ash is very low because the surface of coal fly ash is denser and more stable (Hailong and Aleksandra, 2017). However, with the increase of pH value, the surface of fly ash is dissolved gradually, and more aluminosilicate sol is produced, which is more conducive to the hydration polymerization of hydration products, which is more conducive to the later strength growth. However, with the increase of pH value, the surface of fly ash is dissolved gradually, and more aluminosilicate sol is produced, which is more conducive to the hydration polymerization of hydration products and the later strength growth (Kiacher and Majid, 2017).

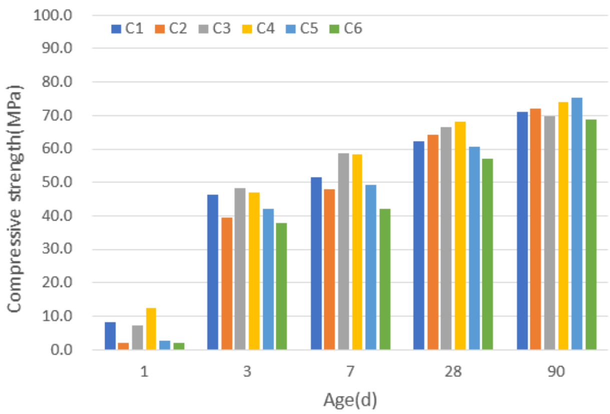

Figure 4: Compressive strength of ordinary concrete in different ages

The compressive strength of alkali activated slag concrete is affected by different fiber content. When the fiber content is 0.9Kg/m3, the strength of 1d and 3d is obviously improved. However, with the extension of hydration age, the effect of fiber on the strength of concrete gradually weakened, and the compressive strength rate is lower than soda ash concrete at 90d. When the fiber content increases to 1.8Kg/m3, the early compressive strength increases a little, and the effect is not obvious. However, after 28d, the later strength increases quickly, and it is obviously higher than soda ash slag concrete at 90d. This change is closely related to the amount and state of fiber distribution in alkali activated slag concrete (Xiao et al., 2017). When the fiber content is 0.9kg/m3 and 1.8kg/m3, the compressive strength of alkali activated slag concrete at 28d is increased by 1.3% and 19.1%, respectively. It is concluded that adding a certain amount of fiber in alkali slag concrete will help to improve the compressive strength of alkali activated slag concrete. After adding composite fiber with different amount based on fly ash, the strength before 28d is lower than soda ash slag concrete, but the strength increases rapidly. The strength after 28d is obviously higher than soda ash slag concrete. The compressive strength and fiber content at 7d decreases from high strength to low strength, but increases with the increase of fiber content after 28d. When the fly ash is mixed with 1.8Kg/m3 fiber, the strength of the fly ash before 7d is lower than fly ash, and the strength after 28d is higher than fly ash.

The effect law of synthetic fiber and fly ash on the compressive strength of ordinary concrete is shown in figure 4:

It shows that the effect of fly ash on the compressive strength of ordinary concrete and alkali activated slag concrete is basically the same, that is, fly ash reduces the early strength before 28d and improves the later strength after 28d. This is because the early hydration of fly ash is not completely hydrated, and its activity is low, mainly working on micro aggregate filling. With the deepening of hydration degree, fly ash reacts with hydrated calcium hydroxide (Hailong and Aleksandra, 2017). The activity is gradually activated, generating a large number of CSH gel, strengthening the compactness of the paste (Kim et al., 2017), thus improving the concrete strength.

Based on replacing some ordinary cement with 25% fly ash, synthetic fibers with different dosage are added. Compared with pure ordinary concrete, the compressive strength is higher than pure ordinary concrete only when the dosage is 0.9Kg/m3 at the 90d. The other days are lower than pure ordinary concrete. Therefore, fly ash is not conducive to the development of early strength of ordinary concrete. After adding 0.9Kg/m3 fiber repeatedly, the compressive strength before 28d is lower than the compressive strength of ordinary concrete mixed with fly ash, but the intensity of 90d is higher than the single fly ash or single fiber. The strength is the highest strength of all groups at that time. When the amount is increased from 0.9Kg/m3 to 1.8Kg/m3, the compressive strength of each age is reduced, so the large amount of fiber is not conducive to the development of compressive strength. This is because the early hydration products are less. In addition, with the increase of fiber content, the fiber cannot be completely wrapped by cement paste, resulting in lower strength (Jinjie et al., 2017).

4. Conclusion

The effect of fiber and fly ash on the mechanical properties of alkali activated slag concrete and ordinary concrete are compared and analyzed. The following conclusion can be summarized: The workability of alkali activated slag concrete is smaller than fly ash. Although the workability of alkali activated slag concrete has been reduced by fiber, the workability of alkali activated slag concrete with different fiber content can still meet the requirements of practical engineering. Fiber greatly improves the compressive strength of two kinds of concrete at the later stage, and the compressive strength of the concrete increases little at the early stage. When the fiber content is 0.9kg/m3 and 1.8kg/m3, the compressive strength of alkali activated slag concrete at 28d is increased by 1.3% and 19.1%, respectively. Ordinary concrete is increased by 6.7% and 9.6% respectively. Fly ash improves the compressive strength of two kinds of concrete after 28d.

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