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Effect of Polypropylene Fiber Admixture on Compressive Strength of Ceramsite Concrete

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Abstract: *This paper analyzes the influence of polypropylene fiber content on the compressive strength of shale ceramsite and fly ash ceramsite concrete. The results show that less polypropylene will have small influence on compressive strength of two types of ceramsite concrete. With the increase of polypropylene fiber admixture, the influence increases first and then decreases. When the amount of polypropylene fiber admixture is 2 kg/m^2, compressive strength of two kinds of ceramsite concrete after 28 days can all have their peak values and the concrete prepared can all reach their highest intensity. When the polypropylene fiber admixture is larger than 2 kg/m^2 compressive strength of two kinds of ceramsite concrete will drop drastically, which will even be lower than the designed strength of the ceramsite concrete.*

Keywords: *Shale Ceramsite, Fly Ash Ceramsite, Polypropylene Fiber, Concrete Compressive Strength*

1. Introduction

Under the environmental governance focuses and model innovation direction , how to reasonably use industrial waste has become a research hotspot. Because ceramsite industry has special advantages in the utilization of solid wastes, the prepared ceramsite concrete with better performance will play a huge role in ensuring a better environment. The most common way in China currently is to use fly ash ceramsite and shale ceramisite as the coarse aggregate to make lightweight concrete. Fly ash ceramsite has the shape of round balls while shale ceramisite has the shape of detritus. Lightweight concrete is featured by light weight, earthquake resistance, frost proof and other performances, so it has a wide application prospect [1]. Generally speaking, we often regard compressive strength test of the concrete as one of the most important indicators to evaluate mechanical properties of concrete. Foreign scholars use polypropylene fiber to replace coarse and fine aggregate in concrete to do a test and the results show that the mixing amount of polypropylene fiber can affect the compression resistance, tensile strength and bending strength of concrete [2-4]. In China, Lu Dong et al. [5] studied the influence of polypropylene content on splitting resistance performance of concrete based on finite elements. Zhou Xingyu et al. [6] studied mechanical properties and damage of polypropylene fiber concrete through multiple scales and the results show that the mixing amount of polypropylene fiber could improve the integrity and residual strength of concrete after damage. Polypropylene fiber is featured by light weight, good toughness, chemical corrosion resistance and low price. At the same time, it has crack resistance characteristics. If it is added to ceramsite concrete, when there are external loads, polypropylene fiber in ceramsite concrete will have collaborative force with the ceramsite concrete, which can reduce extension of cracks [7-12].

In this test, the polypropylene fiber with different quantity will be added to the ceramsite concrete so as to research its influence on compressive strength of fly ash ceramsite concrete and shale ceramsite concrete cubes with two kinds of coarse aggregate grain shapes. This paper, based on the tested data, will explore the optimal mixing amount of polypropylene fiber to the ceramsite concrete.

2. Test Design

2.1 Raw Materials

Cement: Ordinary Portland cement (P.O42.5R) which can meet requirements of Common Portland Cement (GB 175—2007) and has qualified performance and stability, is used in this test. Physical and

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mechanical properties of the cement are shown in table 1.

Table 1 Physical and mechanical properties of the cement

Cement mark	Density (g/cm^3)	Water requirement of normal consistency (%)	Setting time (min)		Bending Strength (MPa)		Compressive strength (MPa)		Specific surface area (㎡/g)
			Initial set	Final set	3d	28d	3d	28d	
42.5 R	3.10	28.6	135	180	4.6	7.2	15.7	45.7	362

Polypropylene fiber: Polypropylene fiber has bamboo-shape appearance and it is as long as 9cm. It is made of soft and tensile materials and its performance indicators are shown in Table 2.

Table 2 Polypropylene fiber performance index

Length (mm)	Diameter (μm)	Density (g/m^3)	Tensile strength (MPa)	Elasticity modulus (MPa)
9	32.7	0.91	469	4236

Coarse aggregate: The size of the fly ash ceramsite grain composition selected is between 8mm and 12mm and that of the shale ceramisite grain selected is between 8mm and 16mm. The fly ash ceramsite has low surface roughness degree while the surface of shale ceramisite is relatively coarse. Its opening gap is slightly higher than the previous one.

Fine aggregate: Ordinary river sand, whose apparent density is 2650kg/m^3, bulk density is 1500kg/m^3 and fineness modulus is 2.6, is used. High-efficiency water reducing agent: No.2 UNF-5 high-efficiency water reducing agent produced by Chemical Factory is powder-like and its water-reducing rate is about 20%. Its mixing amount is 0.6% of the cement amount.

2.2 Design of the Mix Proportion

This test mainly researches the influence of polypropylene fiber to the compressive strength of fly ash ceramsite concrete and shale ceramsite concrete of different mixing amounts. Mixing range of raw materials is selected according to Technical specification for lightweight aggregate concrete structures (JGJT12-2019) and the benchmark mix proportion for two kinds of ceramsite concrete is adjusted. After that the scopes of polypropylene fiber admixture is selected according to Technical specification for application of fiber reinforced concrete (JGJT 221-2010) and the scopes are 0.5kg/m^3, 1kg/m^3, 1.5kg/m^3, 2kg/m^3, 2.5kg/m^3 and 3kg/m^3 respectively. The mix proportion in the test is shown as follows Table 3.

Table 3 Ceramsite concrete mixing proportion

Coarse aggregate types	No.	Mix proportion (kg/m^3)					
		Polypropylene fiber admixture	Cement	coarse aggregate	Fine aggregate	Water	Water reducing agent
Fly ash ceramsite	FACC-0	0	480	718	646	165	2.88
	FACC-1	0.5	480	718	646	165	2.88
	FACC-2	1	480	718	646	165	2.88
	FACC-3	1.5	480	718	646	165	2.88
	FACC-4	2	480	718	646	165	2.88
	FACC-5	2.5	480	718	646	165	2.88
	FACC-6	3	480	718	646	165	2.88
Shale ceramisite	SCC-0	0	480	549	624	175	2.94
	SCC-1	0.5	490	549	624	175	2.94
	SCC-2	1	490	549	624	175	2.94
	SCC-3	1.5	490	549	624	175	2.94
	SCC-4	2	490	549	624	175	2.94
	SCC-5	2.5	490	549	624	175	2.94
	SCC-6	3	490	549	624	17	2.94

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2.3 Test Molding and Curing

Tests are down in accordance with Standard for test method of performance on ordinary fresh concrete (GB/T50080-2016) and Standard for test method of mechanical properties on ordinary concrete (GB/T 50081-2019). The triple non-standard cube mold with the test mode size of 100 ㎜×100 ㎜×100 ㎜ is used in each group. The final compressive strength value tested shall multiply by the coefficient 0.95. First, raw materials should be put into the mixer. After they are mixed for two minutes, they should be placed into the mold. After being vibrated by the shaking table, it will should be placed still for 24 hours and then be demoulded and placed into the constant temperature and humidity box for curing. After three days, seven days and 28 days, the well cured test specimen shall be taken out for compressive strength tests and to research the influence of different kinds of polypropylene fiber admixture on compressive strength of the fly ash ceramsite concrete and the shale ceramsite concrete in different periods.

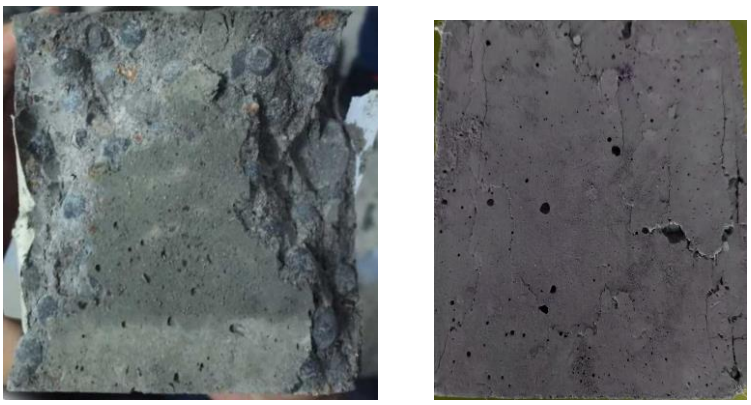
3. Analysis of Test Results

3.1 Testing Phenomenon

Figure 1 and Figure 2 respectively show the failure form of fly ash ceramsite concrete and shale ceramsite concrete after compressive resistance tests when the polypropylene fiber is mixed or not mixed during the same period. As can be seen from Figure 1 (a) and (b), the damage phenomenon of fly ash ceramsite concrete without polypropylene fiber added is relatively obvious. Due to the hoop effect when concrete is compressed, both edges of the concrete test specimens have serious spalling phenomenon. The ceramsite concrete mixed with polypropylene fiber has some obvious cracks on its surface. Careful observation shows that there is no large spalling area on edges of the ceramsite concrete and that the test block is relatively complete.

It can also be found from Figure 2 (a) and (b) that the damage phenomenon of shale ceramsite concrete without polypropylene fiber is more serious than that of the shale ceramsite concrete with polypropylene fiber. The spalling area on the surface of the shale ceramsite concrete without polypropylene fiber is larger than that of the fly ash ceramsite concrete. There are some spalling phenomena as well as some cracks on edges of shale ceramsite concrete with polypropylene fiber.

In the process of compressive test, the stress load gradually increases. When the stress reaches a certain value, you can hear a slight cracking sound inside the test block and cracks gradually appear on the surface from its bottom. As the load becomes larger and larger, the cracks gradually extend and become larger. When there are ultimate loads, the specimen will make greater noises and load values do not change. At that time, the specimen is also destroyed accordingly. However, fragments of fly ash ceramsite concrete and shale ceramsite concrete without polypropylene fiber all splashed off during the test. However, this phenomenon did not occur on the concrete with polypropylene fiber mixed. This shows that the mixing of polypropylene slows down cracks in the ceramsite concrete, restricts brittle failure, thus playing a connecting role. This shows that damaged surfaces of both types of ceramsite concrete have all been improved after the mixing of polypropylene, which greatly reduces the spalling degree.



(a)*Without polypropylene fiber* (b)*With polypropylene fiber*

Figure 1 Failure representation of fly ash ceramsite concrete

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(a)*Without polypropylene fiber* (b)*With polypropylene fiber*

Figure 2 Failure representation of shale ceramsite concrete

3.2 Test Results

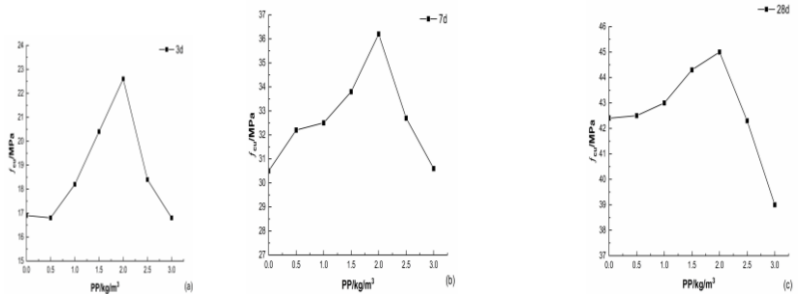
The compressive strength of fly ash ceramsite concrete or shale ceramsite concrete is obtained from the polypropylene fiber with or without polypropylene fiber,as shown in Table 4).

Table 4 Test value of compressive strength of ceramsite concrete

No.	Polypropylene fiber admixture	Compressive strength (MPa)		
		3d	7d	28d
FACC-0	0	16.9	30.5	42.4
FACC-1	0.5	17.4	31.2	42.6
FACC-2	1	21.1	36.2	43.8
FACC-3	1.5	25.5	32.5	45
FACC-4	2	26.3	33.8	46
FACC-5	2.5	19.6	32.7	42
FACC-6	3	18.3	30.6	39.3
SCC-0	0	15.8	29.6	40.6
SCC-1	0.5	16.8	31.2	42.5
SCC-2	1	18.2	32	43
SCC-3	1.5	20.4	36	44.3
SCC-4	2	22.6	33.6	45
SCC-5	2.5	18.4	32.5	40.3
SCC-6	3	16.8	29	38.4

3.3 Analysis of Results

Polypropylene fiber admixture has great influence on compressive strength of fly ash ceramsite concrete and shale ceramsite concrete cubes as shown in Figure 3 and Figure 4. As can be seen from Figure 3 and Figure 4, the compressive strength of ceramsite concrete at different ages shows a trend of increasing first and then decreasing along with the increase of polypropylene fiber admixture.



3 Days *7 Days* *28 Days*

Figure 3 Influence of different polypropylene fiber admixture on the compressive strength of fly ash ceramsite concrete

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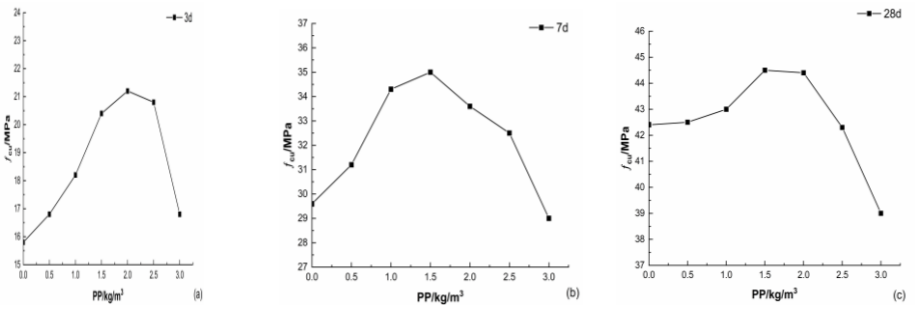
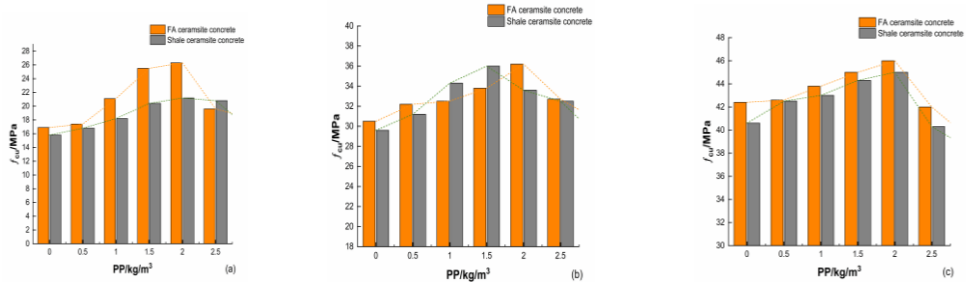


3 Days *7 Days* *28 Days*

Figure 4 Influence of different polypropylene fiber admixtures on the compressive strength of shale ceramsite concrete

When the admixture of fly ash ceramsite concrete is 2kg/m^3, the compressive strength of ceramsite concrete cubes improves (8.5%) compared with the benchmark group without admixture of polypropylene fiber. However, as polypropylene admixture continues to increase, the compressive strength of ceramsite concrete decreases with the increase of fiber. Besides, the compressive strength of fly ash ceramsite concrete when there is much polypropylene fiber is lower than that of the benchmark ceramsite concrete without polypropylene fiber (7.3%). besides, the compressive strength can not reach the required strength in the design. When the admixture to shale ceramsite concrete is 2 kg/m^3, the compressive strength of ceramsite concrete improves (10.8%) compared with the benchmark groups without polypropylene fiber. However, as polypropylene admixture continues to improve, the admixture of fiber is inversely proportional to the compressive strength of the concrete. When the admixture of polypropylene fiber is 3kg/m^3, the compressive strength of shale ceramisite is reduced (4.8%) compared with that of the benchmark group.

Moreover, different scholars have different opinions on whether the polypropylene fiber can improve the compressive strength of the concrete. The analysis of the influence of the polypropylene fiber admixture based on this test conditions and results on the compressive strength of the fly ash ceramsite and the shale ceramsite concrete shows that a small amount or a proper amount of polypropylene fiber added to the fly ash ceramsite concrete or the shale ceramsite concrete can all improve the compressive strength of concrete. However, when it reaches a certain value, excessive polypropylene fiber admixture has negative effects on the strength of concrete. This phenomenon may be caused by the following reasons: the appropriate amount of polypropylene fiber added to the concrete when the test blocks suffer from stress loads restrains the lateral deformation occurred during the failure, slows down the expansion of cracks and plays the role of polypropylene fiber in toughening and resisting the ceramsite concrete. However, excessive polypropylene fiber added will hinder the wrapping effect between cement slurry and aggregate because too much polypropylene fiber between cement slurry and aggregate affects the bonding effect between the two. When the ceramsite concrete suffers from stress, as the loads increase, there will be crack between cement slurry and aggregate, which reduces the compressive strength of the concrete.



3 Days *7 Days* *28 Days*

Figure 5 Comparison of the compressive strength of fly ash ceramsite and shale ceramsite concrete under different polypropylene fiber admixtures

Therefore, the comparison of the compressive strength between fly ash ceramsite and shale ceramisite of different ages in Figure 5 shows that with the same design strength and polypropylene fiber admixture, the strength of fly ash ceramsite concrete at different ages is higher than the shale ceramsite concrete. Because fly ash ceramsite seems to be a round ball and shale ceramisite has the shape of detritus. When the concrete test piece suffers from external loads, the stress distribution of

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round ball fly ash ceramsite is relatively uniform while that of the detritus is relatively concentrated, leading to the result that the compressive strength of shale ceramsite concrete is lower than that of fly ash ceramsite concrete.

4. Conclusion

Polypropylene admixture will have certain influence on compressive strength of the ceramsite concrete. The compressive strength of fly ash ceramsite concrete and shale ceramsite concrete within a certain scope will increase withe the increase of the admixture amount. When the polypropylene admixture is 2kg/m^3, the compressive strength of the fly ash ceramsite concrete and the shale ceramsite concrete within 28 days can all reach their peak value. Some uncontrollable factors in the test process lead to some errors of the test results. However, the analysis of most test data shows that when the admixture of polypropylene fiber is greater than 2kg/m^3, the admixture of polypropylene fiber is inversely proportional to the compressive strength of ceramsite concrete and it is even lower than the strength without polypropylene fiber admixture. This means that proper amounts of polypropylene fiber to the ceramsite concrete can improve the compressive strength of the concrete, but it can also hinders the expression damage of the concrete. However, excessive polypropylene fiber will affect the compressive strength of the ceramsite concrete.

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