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Effect of Double Fly Ash and Rice Husk Ash on Dry Shrinkage Mechanical Properties of Ceramsite Concrete

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Abstract. In this paper, the effects of fly ash and rice husk ash on the drying shrinkage of ceramsite concrete were studied by testing the drying shrinkage amount and the corresponding compressive strength of ceramsite concrete at different ages, and according to the corresponding mechanical properties, the correlation between the shrinkage strain and compressive strength of ceramsite concrete was further explored. The research shows that the drying shrinkage of ceramsite concrete can be effectively reduced by adding 30% fly ash and 15% rice husk ash, and with the increase of rice husk ash content, the compressive strength of concrete also increases gradually. Through fitting analysis, it is found that there is a good curve regression relationship between shrinkage strain and compressive strength of ceramsite concrete, and the regression equation is predicted. Finally, the optimal mixing ratio was determined through experiments, which ensured that the double mixing of fly ash and rice husk ash could reduce the drying shrinkage of concrete and improve the compressive strength of concrete.

Keywords. fly ash, rice husk ash, drying shrinkage, ceramsite concrete

1. Introduction

Ceramsite concrete, as a kind of lightweight aggregate concrete, has multiple properties such as light weight, seismic resistance and thermal insulation compared with ordinary concrete. However, due to the small elastic modulus of ceramsite concrete, compared with ordinary concrete, ceramsite concrete has low strength and weak ability to inhibit shrinkage, leading to the increase of shrinkage deformation, and then the structure cracking affects the overall stability, and the durability of light aggregate concrete is very unfavorable.

In order to solve the above problems, some scholars have conducted research on this, Sun Da Ming[1] found that the drying shrinkage and compressive strength of ceramsite concrete can be affected by changing the particle size, and the drying shrinkage decreases with the increase of particle size .Xia Xu Dong[2]By changing the mix ratio, sand rate and light aggregate content, the factors affecting the drying shrinkage of ceramsite concrete were studied. Ei-ichi Tazawa[3] through the study of admixtures, cement and water-cement ratio and other aspects, to explore the inhibition of self-shrinking phenomenon of high-strength concrete, this paper from the perspective of mineral admixtures, by adding fly ash and rice husk ash to modify ceramsite

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concrete, because fly ash and rice husk ash chemical composition and action characteristics, it will be mixed into ceramsite concrete will have different performance. MAO Wen Ting [4] and Ye Guang[5]The study of rice husk ash by et al. found that it has high pozzolanic activity, filling effect and special porous structure, so it can significantly inhibit the drying shrinkage of ceramsite concrete, while improving the compressive strength of concrete. However, due to its large specific surface area, the workability of ceramsite concrete is poor, fly ash, as a common admixture, has the characteristics of spherical particles, smooth surface, shape effect and filling effect, which can effectively improve the fluidity of concrete, improve the workability of concrete, but also reduce the drying shrinkage of concrete, but because of the early activity is low, the single admixture will lead to the early strength of ceramsite concrete is low.

Based on the above situation, in this paper, dry shrinkage of double-doped fly ash and rice husk ash ceramsite concrete will be tested, and the results will be analyzed and discussed, in order to get the optimal control ratio of double-doped rice husk ash and fly ash, and realize the complementary effect of the two mineral admixtures.

2. Experiment of Double Doped Ceramsite Concrete

2.1 Experimental Raw Materials

The ceramsite concrete materials prepared in this test are rice husk ash, fly ash, cement and ceramsite and other materials for configuration, adding water reducing agent. The cement used Yanji North cement Factory 42.5 ordinary Portland cement; Rice husk ash is obtained by burning rice husk at low temperature, and its main parameters are shown inTable1. Fly ash I grade fly ash, as shown in Table 2. Yanji sand and medium sand are used for fine aggregate with good gradation. Ceramsite using spherical clay ceramsite; Mixing water using tap water; Superplasticizer using high-performance polycarboxylate acid superplasticizer.

Table 1. Indicators of low-temperature rice husk ash /%

Internal composition Composition content	SiO_2	CaO	Al_2O_3	Fe_2O_3	MgO	K_2O	Na_2O	LOI
	91.17	0.63	0.29	0.88	0.42	1.74	0.08	4.79

Table 2. Physical property parameters of fly ash

Fineness (45μm square hole sieve residue) /%	Apparent density/ (kg/m^3)	Specific surface area/ (m^2 /kg)	Water demand ratio /%	Burning loss /%
8.6	2240	453	91	2.0

2.2 Experimental Scheme

In this experiment, loose volume method was used in the mix design of ceramsite concrete, and the ceramsite was soaked in water for 6h before the experiment, and then the surface of the ceramsite was dried; Considering that the research and application of fly ash has been relatively mature, Ma Li Yuan[6], Cai Tian Yong[7]And Tong Bo Hui[8] According to the experimental results, the single fly ash content can reduce the drying shrinkage of concrete to a certain extent, and it is found that the effect is better if the

content is below 30%. Therefore, in the double mineral admixture in this experiment, the fly ash content is fixed as the optimal content 30%, and the rice husk ash content is constantly changed and increased, which are 10%, 15%, 20%, respectively. In order to obtain the optimal dosage of rice husk ash in the double-doped mineral admixture that can reduce the drying shrinkage of concrete, and at the same time make the ceramsite concrete have good workability. The corresponding concrete mix ratio, workability of ceramsite and water absorption rate of ceramsite are shown in Table 3, Table 4, Table 5 and Figure 1.

Table 3. Mix ratio parameter table of ceramsite concrete

No.	Ceramsite concrete mix/(kg/m³)						
	Cement	water	Natural sand	Ceramsite	Fly ash	Rice husk ash	Polycarboxylate superplasticizer
C0	491.85	210.00	572.84	474.72	-	-	2.459
C1	297.97	210.00	572.84	474.72	147.56	49.18	2.459
C2	270.28	210.00	572.84	474.72	147.56	73.74	2.459
C3	245.93	210.00	572.84	474.72	147.56	98.44	2.459

Table 4. Workability test table

No	Bleeding condition	cohesiveness	Slump /mm
C0	No bleeding	Good	44
C1	No bleeding	Good	40
C2	No bleeding	Good	38
C3	No bleeding	Good	37

Table 5. Water absorption rate of ceramsite

Water absorption time	0.5h	1h	2h	3h	5h	6h	24h	48h
Water absorption	6.1	7.6	8.2	8.4	8.5	8.5	8.5	8.6

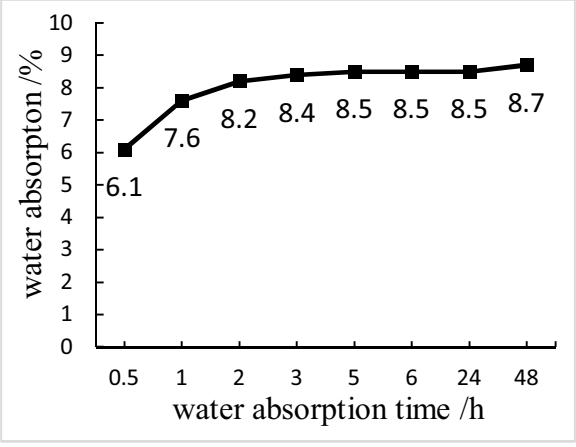

Figure 1. Water absorption test of ceramsite

2.3 Preparation and Curing of Concrete

A small mechanical mixer was used for the preparation of ceramsite concrete, as shown in Figure 2. The size of the test block model was 150mm×150mm×150mm standard mold. There were 48 specimens in total with 12 specimens in each group, and the experimental process was shown in Figure 3, after the specimen was formed, it was put into the standard curing room for curing. After 24h, it was demoulded and continued curing. The curing age was 28d.

Figure 2. Small mixer

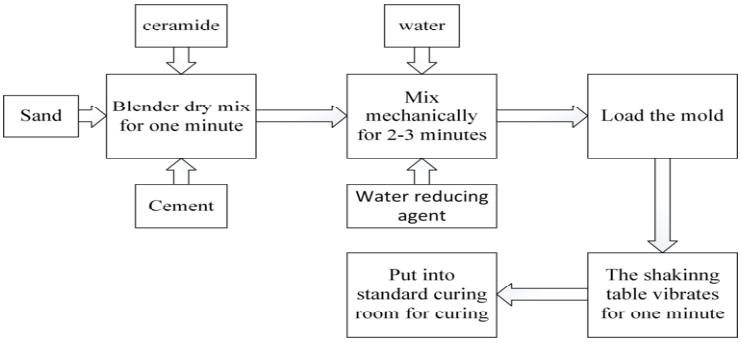

Figure 3. Experimental flow chart

2.4 Experimental Method of Drying Shrinkage of Concrete

The drying shrinkage test method of ceramsite concrete adopts GB/T 5008 2-2009 Standard of Test method for long-term performance and durability of ordinary concrete [9], and the test results are expressed by drying shrinkage rate. The specimens were disassembled 1d after forming and continued to be cured. Micrometer was used to test 3 specimens in each group, and the test age was 3d, 7d, 14d, 28d, 60d and 90d shrinkage value of ceramsite concrete.

The calculation formula is shown in Equation (1)

$$\varepsilon_t = (L_0 - L_t)/L_b \quad (1)$$

Where: ε_t -- drying shrinkage rate of concrete with test age;

L_0-- Initial reading of concrete length, mm;

L_t-- length reading of concrete measured at test age, mm;

L_b-- Measurement scale of concrete, mm;

2.5 Test Method of Compressive Strength of Ceramsite Concrete

The experimental method of axial compressive strength of ceramsite concrete adopts GB/T 50081-2002 [S] mechanical properties test method of ordinary concrete [10]. The mechanical tester is shown in Figure 4. After the specimen was moulded 1d after forming, the curing was continued. The cube specimens with test ages of 3d, 7d, 28d and 60d were tested for axial compressive strength, with 3 specimens in each group.

Figure 4. Mechanical test instrument

3 Experimental Results and Analysis of Double Doped Ceramsite Concrete

3.1 Influence of Double Rice Husk Ash and Fly Ash on Compressive Strength of Ceramsite Concrete

As can be seen from Figure 5, when the fixed fly ash content is 30% and other factors remain unchanged, rice husk ash replaces cement (10%, 15%, 20%) with different proportions and other qualities, it can be seen that the early strength of the experimental group is lower than that of the reference group .The higher the rice husk ash content, the lower the early strength, showing a downward trend ; Analysis of the reason is that the strength of ceramsite concrete in the early stage is mainly supported by the hydration of cement, the experimental group part of the cement is replaced by the same amount, the porous structure of rice husk ash will absorb part of the water, so that its hydration process is weakened, and fly ash and rice husk ash in the early stage almost do not participate in the hydration reaction, resulting in the early strength reduction ;With the progress of curing, when the strength reached 28d, the strength of the experimental group increased significantly in the later period, and the strength of concrete gradually increased with the increase of the content of rice husk ash. When the content of rice husk ash was 20%, the compressive strength reached the maximum, which was 3.9% higher than the strength of the benchmark concrete, meeting the requirements of mix ratio design.

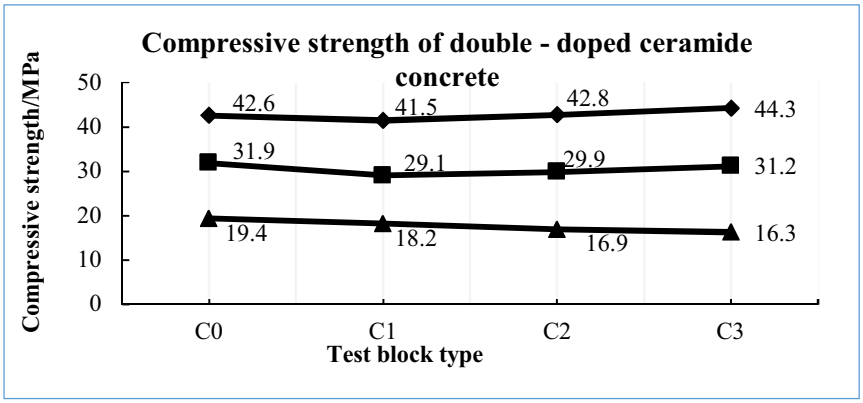

Figure 5. Influence of double fly ash and rice husk ash on compressive strength of ceramsite concrete

3.2 Effects of Double Rice Husk Ash and Fly Ash on Drying Shrinkage of Ceramsite Concrete

It can be seen from Figure 6 that compared with the reference concrete , the early mineral admixture has less influence on the drying shrinkage of ceramsite concrete. With the growth of age, the development rate of concrete drying shrinkage increases. From 7d to 28d, the growth rate of drying shrinkage in the experimental group with mineral admixture is smaller than that in the reference group. This indicates that rice husk ash and fly ash inhibit the drying shrinkage of concrete to a certain extent and weaken the drying shrinkage of concrete, When the fly ash content was kept unchanged and rice husk ash was used to replace cement, the drying shrinkage rate decreased first and then increased. But generally speaking, the drying shrinkage rate of the three experimental groups was lower than that of the reference group .When the rice husk ash content reaches 15%, the inhibition effect is the most obvious, and the drying shrinkage is 384×10 at the age of 90 days^{-6}, the drying shrinkage was 31.3% lower than that of the reference group .It can be seen that the drying shrinkage of ceramsite concrete can be effectively reduced by mixing fly ash and rice husk ash, which mainly acts on the middle and late stage of concrete. Based on the Angle of drying shrinkage of concrete, double mixing of 30% fly ash and 15% or 20% rice husk ash can effectively reduce the drying shrinkage of ceramsite concrete.

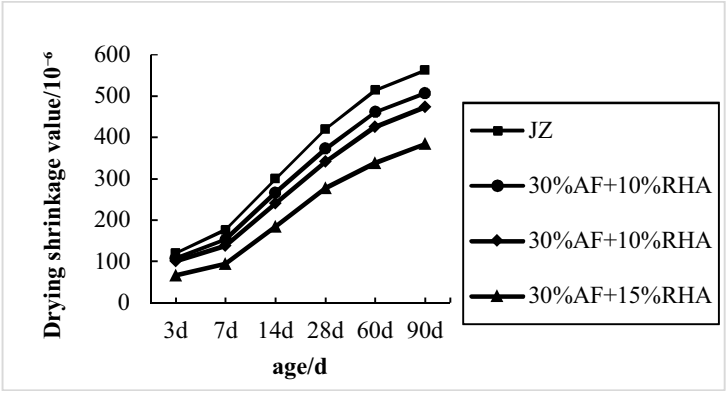

Figure 6. Effects of fly ash and rice husk ash on drying shrinkage of ceramsite concrete

3.3 Relationship between Compressive Strength and Shrinkage Strain of Twin-Doped Ceramsite Concrete

Based on the above experimental results, it can be concluded that the drying shrinkage and the change of relevant mechanical properties of ceramsite concrete are related to hydration. In order to explore the correlation between the shrinkage strain and compressive strength of ceramsite concrete, curve fitting analysis is carried out on both of them, and the regression relationship and curve fitting equation between the shrinkage strain and compressive strength obtained are shown in Figure 7 and Table 6. As can be seen from the chart, the degree of fitting between shrinkage strain and compressive strength of double-doped ceramsite concrete is significant, and its correlation coefficient is R^2Both of them are greater than or equal to 0.96, indicating a good correlation between the compressive strength of double-doped ceramsite concrete and the shrinkage strain. The curve model is shown in Equation (2), where B1 and B2 represent the quadratic coefficient and one-time coefficient of the regression curve equation. It can be seen that the rice husk ash content keeps increasing, and the value of B1 and B2 decreases, and the curve is further away from the Y-axis. In addition, the growth rate of shrinkage strain in the Y direction is weakened, and the curve is more gentle , It indicating that double-doped rice husk ash and fly ash can inhibit dry shrinkage, and under the condition of the same shrinkage strain, can further increase the compressive strength of the ceramic concrete. P is the intercept of the regression curve equation, meaning the shrinkage strain when the compressive strength is zero. The intercept of group C3 is the smallest, which indicates that the inhibition ability of ceramsite concrete with 30% fly ash and 15% rice husk ash is the best when the intensity is the same.

$$Y=B_1\times X+B_2\times X^2+P \tag{2}$$

Where: Y -- Shrinkage strain of concrete (10^{-6});
X-- Compressive strength of concrete (MPa);
B_1、B_2-- secondary term coefficient, primary term coefficient;
P—Intercept.

Table 6. Fitted regression equation table

Experimental group	Fitting curve	R^2
C0	$Y=0.53X^2-24.05X+388.32$	0.96
C1	$Y=0.34X^2-14.09X+244.87$	0.98
C2	$Y=0.32X^2-13.99X+212.71$	0.97
C3	$Y=0.27X^2-10.74X+186.89$	0.97

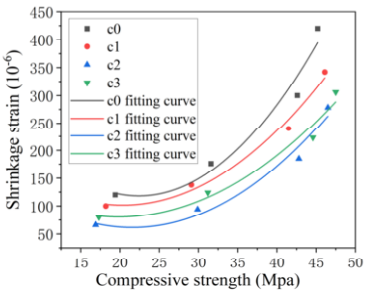

Figure 7. Fitting regression curves

3.4 Analysis and Discussion of Drying Shrinkage Experiment of Double Doped Ceramsite Concrete

The drying shrinkage of ceramsite concrete is essentially the concrete hardening shrinkage caused by the evaporation of water in the pores .Concrete has very fine pores inside (generally connected pores), the water in concrete cannot fully participate in cement hydration, not participate in cement hydration, part of the water will go into the pores, when the external humidity is less than 100%, it will cause the evaporation of water in the pores, resulting in the decline of the capillary meniscus, resulting in negative pressure, the smaller the capillary radius, The greater the negative pressure generated by water evaporation, which is manifested in the macro shrinkage of cement slurry and concrete structure shrinkage.

1) According to aim and goff model theory, when the whole internal material of concrete is regarded as a multi-component system, there is the tightest packing in the system. Because the fineness of rice husk ash and fly ash is finer than that of cement particles, the micro-aggregate effect can occur inside. Because fly ash itself is spherical particles, after it is filled between cement particles. It can play the role of flocculating and active filling; Rice husk ash can refine the internal pore structure to a certain extent, and rice husk ash can absorb a certain amount of water on its surface in the early stage. When the internal water evaporates, the water on the surface of rice husk ash will enter the microscopic pores of concrete, which not only plays a curing role in the concrete, but also weakens the negative pressure in the pores, Zhuang Yi Zhou said [11] the study found that concrete by adding a certain amount of rice husk ash can effectively reduce the number of harmful and harmless pores, reduce the average pore size, and optimize the internal pore structure.

2) The pozzolanic activity of rice husk ash is similar to that of fly ash, and there is no shaped SiO_2 in rice husk ash .The content is also high, and the two admixtures can effectively absorb the Ca(OH) formed during cement hydration.$_2$ Therefore, the hydration process can be increased in the middle and late stage, so that the hydration can generate more favorable C-S-H gel, and also the absorbed Ca $(OH)_2$ Grain refinement, further make its structure more dense, improve the compressive strength.

4 Experimental Conclusion of Double Doped Ceramsite Concrete

1) Double fly ash and rice husk ash can significantly inhibit the drying shrinkage of ceramsite concrete, and the drying shrinkage of ceramsite concrete decreases with the increase of rice husk ash content under the condition that the fly ash content remains unchanged.

2) There is a good curve regression relationship between shrinkage strain and compressive strength of ceramsite concrete, and the curve regression equation is obtained through fitting.

3) The optimal double mixing ratio of 30% fly ash and 15% rice husk ash to inhibit the drying shrinkage of ceramsite concrete was determined through experiments.

4) Under the condition that fly ash content is maintained at 30%, with the increase of rice husk ash content, the initial strength is lower than that of the reference concrete, but the compressive strength of 28d is gradually higher than that of the reference concrete, which proves that their action time is in the middle and late period, and a certain amount of rice husk ash can increase the strength of ceramsite concrete.

5) Explanation of the physicochemical mechanism of rice husk ash inhibiting ceramsite concrete. On the macro level, its fine particle size can fill the pore structure and reduce harmful pores. On the micro level, its silicon content is high, which can further promote hydration reaction, make the structure more uniform and more dense, inhibit dry shrinkage, and enhance compressive strength.

Acknowledgments

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