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The effect of Stone Powder content of dolomite manufactured sand on the cement Hydration

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Abstract. In this paper, the effects of different stone powder content (5%, 10%, 15%, 20%, 25%) of dolomite manufactured sand on the workability and mechanical properties of cement were studied. The influence of stone powder content on the hydration products and microstructure of cement were studied by XRD, SEM. The results show that the workability and mechanical properties of cement can be improved obviously when the content of stone powder is less than 10%, and the influence of stone powder on hydration products and Microstructure of cement is small.

1. Introduction

In recent years, with the continuous development of construction industry in China, the consumption of concrete has increased year by year, natural sand resources are increasingly scarce, and the natural sand that can be mined is less and less^[1]. Therefore, the waste stone produced manufactured sand is favourable for local rock resources or engineering disposal. However, a large amount of stone powder will be produced in the process of producing manufactured sand, and the difference stone powder content is one of the most important characteristics of the difference between the manufactured sand and the natural sand. Therefore, the determination of the suitable content of manufactured sand stone powder and the influence of the stone powder content on the performance of concrete have become one of the hot issues concrete. Zhang Rulin^[2] studied the effect of different stone powder content on the performance of concrete. The results show that the optimum stone powder content is about 10%, and the workability and mechanical properties of the concrete reach the best state. When the stone powder content exceeds 10%, the performance of the prepared concrete decreases significantly. Xue Yuan^[3] studied the influence of the stone powder content in manufactured sand on the properties of concrete. The results show that when the stone powder content is between 8% and 16%, the concrete and its workability are the best and the strength is higher. Cao Zhiwei^[4] studied the influence of stone powder content on the properties of mortar. The results show that when the stone powder content in the sand is less than 4%, the mortar is easier to separate and permeate, which leads to poor workability. When the stone powder content is more than 4% and less than 8%, the performance of mortar has no obvious change. When the stone powder content is controlled in the range of 8% and less than 18%, the fluidity decreases. The results of the study by Tahir Celik^[5] show that the compressive strength of concrete is still higher than that of the control group without stone powder, even if the stone powder content in the sand is as high as 30%. In other words, the normal content of stone powder (5-20%) will not adversely affect the compressive strength of concrete.



The above studies are all the effects of the content of dolomite manufactured sand on the workability and mechanical properties of concrete, and the lack of research on the hydration process of cement. In this paper, the influence of stone powder content in dolomite manufactured sand on the workability and mechanical properties of cement and the hydration products of cement are discussed.

2. Experimental details

2.1 Materials

Cement: 42.5 grade ordinary Portland cement of Shandong Lucheng cement. The physical and mechanical properties are shown in Table 1; Stone powder: dolomite manufactured sand with a particle size of less than 75 μm . The microstructure of the stone powder is shown in Fig.1. It can be seen from Fig.1 that the main chemical composition of dolomite powder is SiO_2 , and that of mineral powder is $\text{CaMg}(\text{CO}_3)_2$; sand: dolomite manufactured sand with fineness modulus 2.4.

Table 1. Cement technical specifications

Cement type	Standard consistency water consumption (%)	Density (g/cm^3)	Setting time (min)		Compressive strength (MPa)		Flexural strength (MPa)		specific area (m^2/kg)
			Initial	Final	3d	28d	3d	28d	
P.O 42.5	28	3.08	170	225	25.9	48.6	5.1	8.5	365

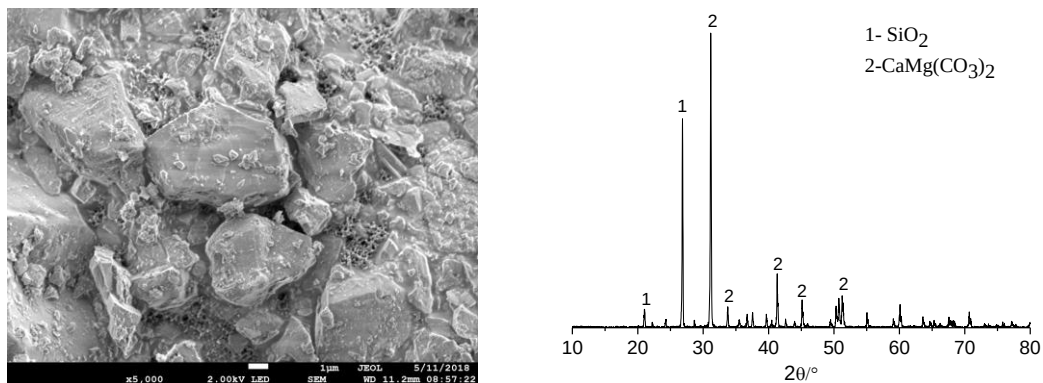


Figure 1. SEM and XRD of the dolomite powder

2.2 Methodology

2.2.1 Analysis of workability and mechanical properties of cement. In order to analyze the influence of stone powder content of dolomite manufactured sand on cement hydration, the cement was replaced by 5%, 10%, 15%, 20%, 25% of stone powder, the standard consistency water consumption and setting time of stone powder replacing part of cement were measured according to the Chinese standard *consistency water consumption, setting time and stability test method of cement* (GB/T1346), According to *The test method of cement mortar strength* (GB/T17671), the strength of cement mortar samples replaced by stone powder for 3 days and 28 days was examined.

2.2.2 Analysis of hydration products of cement. The mineral composition of cement hydration products of different age (3d, 28d) was determined by Ultima IV X-ray diffractometer (XRD). The instrument has a copper target with wavelength $\lambda=0.154\text{nm}$, operating voltage of 40kV, working current of 40mA and scanning range of 5 to 70 degrees.

The microstructure of cement hydration products with 25% stone powder content was studied by JSM- 7800F field emission scanning electron microscope (SEM).

3. Test results and discussion

3.1 Effect of the stone powder content on the standard consistency water consumption of cement

Fig.2 shows the effect of different stone powder content on the standard consistency water consumption of cement. As can be seen from figure 2, the standard consistency water consumption of the cement is 25.6%, the stone powder content increases from 5% to 15%, the standard consistency water consumption of cement increases 1.1%, the main reason is the particle size of the stone powder is smaller than the cement. When the same mass is replaced, the specific surface area and the water absorption increase, the standard consistency water consumption of cement increases. However, when the stone powder content increases to 20%, the standard consistency water consumption decreases, the overall specific surface area decrease is the dominant factor, the standard consistency water consumption of cement decreases.

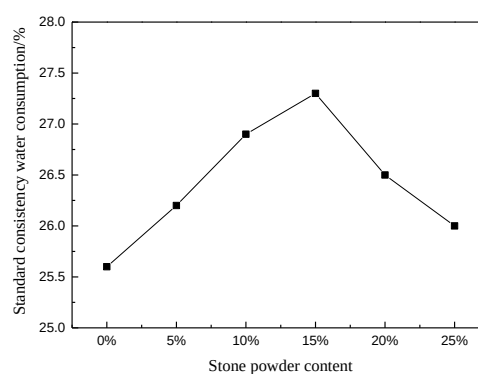


Figure 2. Effect of the stone powder content on the standard consistency water consumption of cement

3.2 Effect of the stone powder content on the setting time of cement

Fig. 3 shows the effect of different stone powder content on the setting time of cement. As can be seen from figure 3, the initial setting time and final setting time of cement are 152 min and 225 min. With the increase of the stone powder content, the initial setting time decreases. When the stone powder content is 10%, the setting time is the shortest, the initial setting time is 111 min, and the final setting time is 211 min. The main reason is that the particle size of stone powder is smaller and the specific surface area is larger. With the increase of the stone powder content, the free water of early cement hydration is less, the cement is easy to reach the early strength, and the initial setting time is shortened. However, when the stone powder content is more than 20%, the cement clinker decreases relatively and plays a dilution role to a certain extent. Under the same cement hydration degree, it takes a longer time to reach the same hardness of the sample.

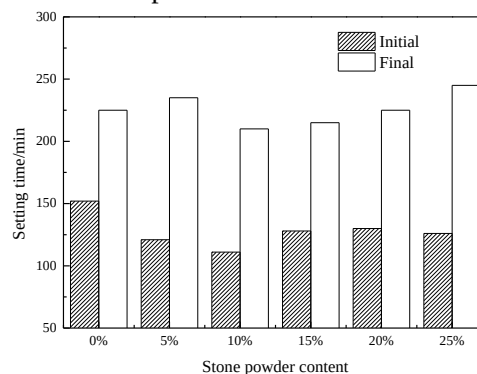


Figure 3. Effect of the stone powder content on setting time of cement

3.3 Effect of the Stone Powder content on Mechanical Properties of cement

Fig. 4 shows the effect of different stone powder content on the compressive strength of cement. As

can be seen from figure 4, when the age is 3 days, the compressive strength of cement is 26.2 MPa, when the stone powder content is less than 10%, the compressive strength is 32.9 MPa, which is higher than cement, and the increase of compressive strength is favorable. when the stone powder content is more than 10%, the compressive strength gradually decreases. The main reason is that with the increase of stone powder content, stone powder fills the harmful pore in concrete, resulting in more compact structure and increased strength. But when the reasonable stone powder content is exceeded, the water demand will be greatly increased, the slurry is difficult to mix evenly, and the uniformity and compactness will decrease. Therefore, Under the condition of certain water consumption in actual construction, the stone powder content should not exceed 10%.

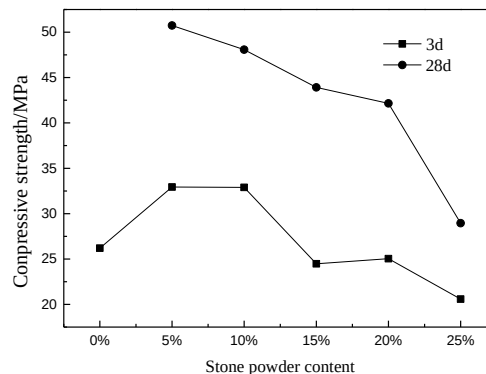


Figure 4. Effect of the stone powder content on the compressive strength of cement

3.4 Effect of the stone powder content on hydration products of cement

Because the manufactured sand is usually obtained by mechanical crushing, the stone powder produced by minerals of different lithology in the process of crushing will also have different particle gradation and micro-morphology. The cement was replaced by 5%, 10%, 15%, 20% and 25% of the stone powder, and the size of the cement paste test block was 40mm×40mm×160mm. The hydration products of the cement paste were analyzed after 3 days and 28 days of age. The microstructure of the cement paste test block with 25% stone powder content was analyzed as shown in Fig. 5 ~ Fig.6. As can be seen from figure 5, when the age is 3 days, the highest peak of Ca(OH)_2 is the mortar sample with 10% stone powder content, followed by the mortar sample with 20% stone powder content. There are uniform diffraction peaks around 18° , 29° , 34° , 47° and 51° . These are Ca(OH)_2 and $\text{CaMg(CO}_3)_2$ without cement hydration products C-S-H and Aft. Because C-S-H itself is non-crystalline, and X-ray diffraction can only be used to detect crystals, while Aft may be due to its low content and has not been detected^[6-7]. $\text{CaMg(CO}_3)_2$ is mostly stone powder itself. In addition to the above-mentioned substances, there is a small amount of unhydrated cement clinker C_3S . At the age of 28 days, the diffraction intensity of Ca(OH)_2 peak line increased, indicating that a small amount of stone powder participates in hydration reaction at the later stage of hydration.

As can be seen from figure 6, when the age is 3 days, there are more stone powder particles, the structure of hydration products is looser, and a small amount of C-S-H and Ca(OH)_2 . When the age is 28 days, the hydration products increase obviously, and the structure of stone powder is more compact. There are Aft, C-S-H and Ca(OH)_2 , but the microstructure of cement does not change obviously after adding stone powder.

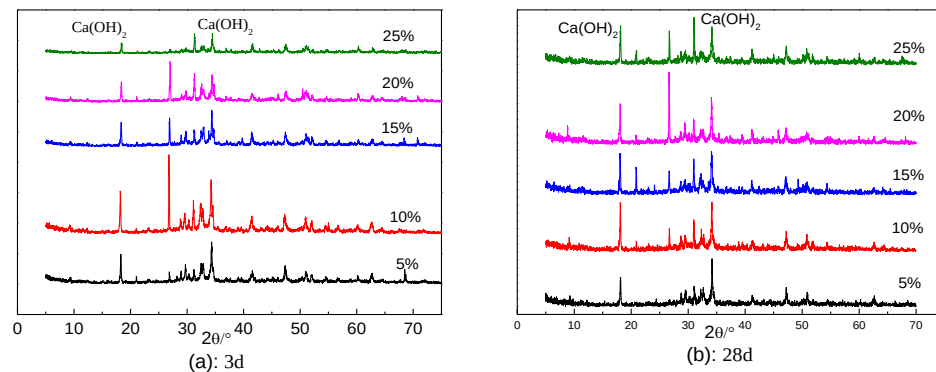


Figure 5. XRD of cement paste test block with different stone powder content

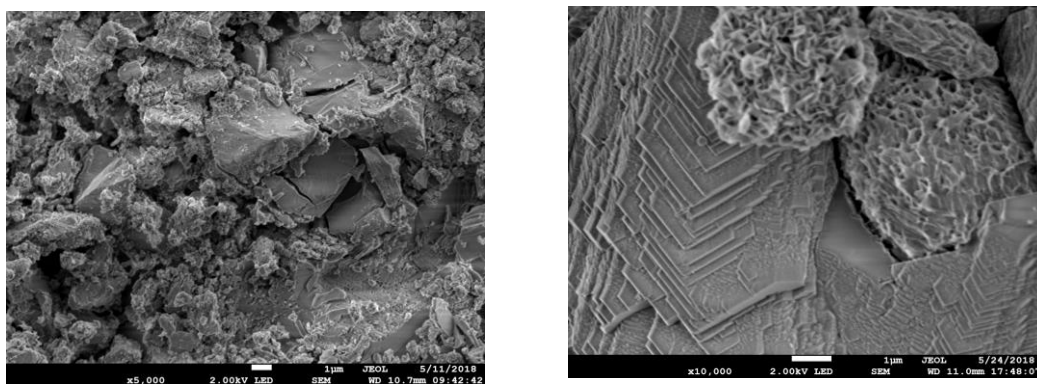


Figure 6. SEM of cement paste test block mixed with 25% stone powder

4. Conclusions

(1) With the increase of the stone powder content, the standard consistency water consumption of cement increases. But when it increases to 20%, the standard consistency water consumption and the initial setting time of cement decreases. When the stone powder content is less than 10%, the initial setting time interval is shortened. when it is larger than 10%, the final setting time is delayed with the increase of stone powder content. But on the whole, the final setting time is close to the non-mixed stone powder.

(2) With the increase of the stone powder content, the compressive strength of cement increases gradually. However, as the proportion of stone powder instead of cementitious material increases, the compressive strength decreases gradually due to dilution.

(3) With the development of cement hydration, the cementitious system gradually densified and the hydration products increase. The hydration products of the system are mainly C-S-H and Ca(OH)_2 . It can be seen that the stone powder particles and a small amount of stone powder was involved in the secondary hydration in the later stage of hydration. However, generally speaking, stone powder has little effect on the hydration of cement and the microstructure of its hydration products.

Acknowledgments

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