Influence of Stone Powder on Properties of Concrete with Low Cementitious Materials

ZHU Yun, WEN Chaokai and CHEN Jing

China West Construction Southwest Group Co., Ltd., Chengdu 610052, China
E-mail: zhuwh712@163.com

Abstract. With the growing shortage of natural sand, mechanism sand become an important source of sand. And the large amount of low quality is a common phenomenon of the mechanism sand, which mainly reflecting in its bad gradation and grain shape and the results will lead to the cementitious materials and water consumed greatly. The influence of stone powder of high quality mechanism sand on C30 concrete properties is studied. The results show that the proper amount of stone powder could improve the gradation of mechanism sand, increase the paste volume and fill in the void among particles. The workability, compressive strength, permeability and frost resistance of the mechanism sand concrete will be improved on the basis of the content of stone powder, and the optimum range of stone powder content of mechanism sand is 9% to 15% for the C30 concrete.

1. Introduction
It is important to develop and research the mechanism sand, called artificial sand, since the natural riverine sand has become increasingly strained. Even though the mechanism sand is adequate, the quality of that is so poor that it owns harmful grain gradation and grain shape, others are worth exploring. A number of studies have shown that the quality of mechanism sand affects the amount of cementitious materials and water consumption of concrete, especially influence of the low strength concrete[1]. Cementitious materials of the C30 fresh concrete generally above 330kg/m³, part of the region and even reach 380kg/m³, and improve the amount of cementitious materials is an effective measure to reduce the risk that the strength of concrete is less stable. Choosing the high-quality aggregate is so significant that it can reduce water consumption and cementitious materials, but improve the quality of concrete[2].
Less than 0.075mm partial is known as the stone powder in mechanism sand. There are different opinions for the influence of stone powder content on concrete performance of different scholars[3,4], someone hold that it will reduce the performance of the concrete and the others consider that it has the best content. Whether the results are accurate or not, it is necessary to verify[5]. Because, after all, the studies are researched based on the ordinary concrete with the high-quality aggregate, low cementitious materials, low water consumption and the concrete low strength is no systematic studied. Therefore, it is of important significance to carry out effects of influence of stone powder content of high-quality mechanism sand on C30 concrete with cementitious materials in the 300kg/m³ or even lower.

2. Experiment
2.1. Raw materials
(1) Cement: P.O42.5 cement produced by Sichuan Lafarge are used in the test. Their basic performance is shown in Table 1.

| Table 1. Basic performance of cement. |
|--------------------------------------|
| Cement     | Specific area (m²/Kg) | Flexural Strength (MPa) | Compressive Strength (MPa) | Density (g/cm³) | Stability |
|------------|-----------------------|-------------------------|---------------------------|-----------------|-----------|
| P.O42.5    | 349                   | 6.1                     | 9.3                       | 28.1            | 49.6      | 3.13      | Conforming |

(2) Fly ash: Grade I fly ash are used in the test. Their basic properties are as follows: fineness of 7.6%, SO₃ addition of 0.54%, loss on ignition of 2.01%, water requirement 95%.

(3) Gravel: 5~25mm gravel are used in the test, mud addition of 0.1%, apparent density 2740kg/m³, crushing value of 4.9%.

(4) Mechanism sand: Fineness modulus of 2.6, mud addition of 0.2%, apparent density 2740kg/m³, grade of Machine-Made Sand is shown in Table 2.

(5) Superplasticizer: Polycarboxylate superplasticizer are used in the test. Solid addition of 12%.

| Table 2. Grade of mechanism sand. |
|----------------------------------|
| Screen size (mm)                |
| Cumulative sieve residue (%)    |
| 4.75                             | 2.36  | 1.18  | 0.60  | 0.30  | 0.15  | 0.075  |
| 1.2                              | 9.4   | 32.7  | 56.1  | 75.3  | 86.8  | 89.4   |

2.2. Mix design
The influence of stone powder of mechanism sand on the workability, mechanical properties and permeability of the concrete is studied for the purpose of analyzing stone powder of mechanism sand of its influence on concrete.

The mechanism sand used in the experiment is to remove the particles which is less than 0.075mm, by designing the amount of stone powder is 0%, 3%, 6%, 9%, 12%, 15%, 18% and 21% respectively to replace mechanism sand. The influence of stone powder content of mechanism sand on properties of C30 concrete with low cementitious materials is researched. Test mix proportion is shown in Table 3.

| Table 3. Mix proportion of concrete. |
|-------------------------------------|
| Sample No. | Stone powder | Cement | Fly ash | Mechanism sand | Gravel | Water | Superplasticizer (kg/m³) |
|------------|--------------|--------|---------|----------------|--------|-------|-------------------------|
| JP-1       | 0            | 240    | 60      | 940            | 1030   | 135   | 3.4                     |
| JP-2       | 28           | 240    | 60      | 912            | 1030   | 135   | 3.9                     |
| JP-3       | 56           | 240    | 60      | 884            | 1030   | 135   | 4.3                     |
| JP-4       | 85           | 240    | 60      | 855            | 1030   | 135   | 4.6                     |
| JP-5       | 113          | 240    | 60      | 827            | 1030   | 135   | 4.7                     |
| JP-6       | 126          | 240    | 60      | 814            | 1030   | 135   | 5.2                     |
| JP-7       | 169          | 240    | 60      | 771            | 1030   | 135   | 5.5                     |
| JP-8       | 197          | 240    | 60      | 743            | 1030   | 135   | 5.9                     |
3. Results and analysis

3.1. Influence of stone powder on workability of concrete

The workability test results is shown in Figure 1. When the mechanism sand has no limestone powder, there is poor workability and easy bleeding isolation of concrete. With the stone powder content of mechanism sand increasing, the working performance of concrete mixture is gradually improved, as it is between 9%~15%, the concrete mixture has good workability and excellent various aspects performance. Accounting for 12% of mechanism sand, the slump and slump spread of fresh concrete are 240 mm and 610 mm respectively, delivery time of inverted slump cone of 3.5s and the working performance of C30 concrete with low cementitious material content of 300kg/m$^3$ has reached or exceeded the performance of ordinary C30 concrete. The working performance of concrete increasingly become so bad that too much stone powder of mechanism sand is not conductive to concrete with the increase of stone powder content of mechanism sand. So, the stone powder content of mechanism sand should be range of 9%~15% on C30 concrete with low cementitious materials. Complete removal of stone powder particles in mechanism sand will also affect the whole graded of concrete system and make graded appeared interrupted, and the cement slurry will be reduced, likewise, the working performance of concrete mixture is detrimental with low cementitious materials. To change the gradation of concrete system and the slurry of concrete mixture, the stone powder content of mechanism sand should be improved appropriate. As it is too much stone powder in mechanism sand, it will adsorb more water and superplasticizer, resulting in high viscosity and content superplasticizer, which is adverse to the workability of concrete mixture.

3.2. Influence of stone powder on compressive strength of concrete

The compressive strength results is shown in Figure 2. When the mechanism sand has no limestone powder, the compressive strength of C30 concrete is low. With the stone powder content of mechanism sand increasing, the compressive strength of C30 concrete gradually increases, and when the stone powder content is 12%, the compressive strength reaches the maximum. However, too much stone powder is not conducive to the compressive strength of C30 concrete. Complete removal of stone powder particles in mechanism sand will also affect the whole graded of concrete system and make graded appeared interrupted, and the cement slurry will be reduced, likewise, the working performance of concrete mixture is detrimental with low cementitious materials.
The test results shown in Figure 2, which indicates that it is detrimental to the compressive strength of concrete with the mechanism sand has no limestone powder, and it is also especially obvious for concrete with low amount of cementitious materials that the 28d compressive strength of concrete is only 30.1MPa. Increasing the dosage of stone powder of mechanism sand, the compressive strength of concrete is improved. When the stone powder content is 12%, the 28d compressive strength can reach up to 42.8MPa. When the content reaches 21%, the compressive strength of concrete decreased, and lower than the group JP-1. Therefore, in order to ensure the compressive strength of concrete with low amount of cementitious materials, the stone powder content of mechanism sand should be 9%~15%. Effects of stone powder content of mechanism sand on the mechanical properties of concrete is mainly reflected in the following aspects:
The stone powder of mechanism sand can improve the gradation system of concrete;
The stone powder of mechanism sand can accelerate the hydration of cement and mineral admixture;
The stone powder of mechanism sand can react to some substance in cement and promote the degree of concrete density, as a certain active substance.
The test results also show that too much stone powder of mechanism sand is not conductive to the compressive strength of concrete, for it can undermine whole graded system and absorb more water, thereby limiting the hydration of cement and mineral admixture.

3.3. Influence of stone powder on hydraulic permeability of concrete
Hydraulic permeability is one of the most important indexes to evaluate the compactness and permeability of concrete, and it is also an important index to evaluation low strength concrete. This section researches the influence of stone powder content on permeability of C30 concrete with low amount of cementitious materials. Test results are shown in Table 4.

| Stone powder (%) | 0 | 3 | 6  | 9 | 12 | 15 | 18 | 21 |
|------------------|---|---|----|---|----|----|----|----|
| Relative permeability coefficient/ (10^-6 mm/s) | 10.34 | 8.99 | 3.13 | 1.22 | 0.98 | 1.33 | 1.94 | 4.12 |

The test results show that the permeability of concrete falls after increases first along with the stone powder content of mechanism sand increased. C30 concrete with low amount of cementitious materials and progressively increased stone powder content has a poor permeability and the gradation system and compactness will be improved. If the stone powder content of mechanism sand, such as more than 15%, up to 21%, this need for more cement wrapped in powder particle surface that can destroy the concrete system and affect the compactness and permeability of concrete. In order to ensure hydraulic anti-permeability of concrete with low amount of cementitious materials, the stone powder content of mechanism sand should be controlled in the range of 9%~15%.

3.4. Influence of stone powder on frost resistance of concrete
The influence of stone powder content with 0%, 6%, 12% and 18% on frost resistance of C30 concrete with low amount of cementitious materials is researched. Test results are shown in Table 5.

| Sample No. | Stone powder (%) | Relative dynamic elastic modulus (%) | Frost resistance grade |
|------------|------------------|--------------------------------------|------------------------|
|            |                  | 50 | 100 | 150 |                           |
| JP-1       | 0                | 99.2 | 75.9 | 50.9 | F100                   |
| JP-3       | 6                | 99.1 | 85.9 | 68.9 | >F150                  |
| JP-5       | 12               | 99.0 | 94.2 | 75.6 | >F150                  |
| JP-7       | 18               | 99.0 | 86.1 | 61.3 | >F150                  |
In our study in this particular study we have some things good and some things bad, but overall, this—these would relatively good with the addition of stone powder in the mechanism sand. As the stone powder content of mechanism sand increased, the frost resistance of concrete is aggrandized first and then decreased. When the stone powder content is 12%, the frost resistance of concrete is best. Continue to improve the stone powder content of mechanism sand, the frost resistance of concrete becomes worse. More holes and poor frost resistance will be generated of C30 concrete with few or no stone powder. Gradually improve the stone powder content can make gradation more reasonable and more compact of concrete, and react with some substance in cement and promote the structure of concrete more compact stone powder, as a certain activity. But the filling effect will be weakened with too much stone powder in the mechanism sand, and more water absorbed that will undermine whole graded system and limit the hydration of cement and mineral admixture to reduce the frost resistance of concrete.

4. Conclusion

Footnotes should be avoided whenever possible. If required they should be used only for brief notes that do not fit conveniently into the text.

- The influence of stone powder of high quality mechanism sand on properties of C30 concrete is studied. The results show that the proper amount of stone powder could improve the gradation of concrete system, increase liquidity, improve the overall performance of concrete and make the structure more compact. When the stone powder content of mechanism sand is 9%-15%, the concrete has better working performance and mechanical performance;
- The stone powder of mechanism sand is good for compact and hydraulic anti-permeability of concrete. The optimal hydraulic anti-permeability properties of concrete will be reached as the stone powder content of mechanism sand is 12%;
- The frost resistance and strength of concrete can be increased with the proper amount of stone powder, and the best properties of concrete react as the amount of stone powder in mechanism sand is 12%.

5. References

[1] Zhao, S., & Yu, J. (2016). Effect of mechanism sand quality on concrete quality. Construction Technology. Zhao Shemin and Yu Jun 2016 Effect of Mechanism Sand Quality on Concrete Quality (China: Construction Technology) pp 577-579
[2] Cai, J. W., Bei-Xing, L. I., Zhou, M. K., & Xiao-Man, H. U. (2006). Effects of crusher dust on properties of low/medium strength concrete with manufactured sand. Journal of Wuhan University of Technology, 28(4), 27-30.
[3] Song, S., Bao, W., & Jin, D. (2013). Research on performance of concrete with low cementitious material content based on the high-quality aggregate. Concrete, 30(10), 157-159.
[4] Yan, Y., Wang, Y. L., & Zhou, M. K. (2007). Effects of the amf contents of mfa on performances of the c30 pump concrete. Journal of Wuhan University of Technology.
[5] Wang, J., Zhou, M., Tusheng, H. E., Guoju, K. E., & Gong, C. (2008). Effects of stone dust on resistance to chloride ion permeation and resistance to freezing of manufactured sand concrete. Journal of the Chinese Ceramic Society, 36(4), 482-486.