Technical Application of Machine-made Sand in the Production of the Commercial Concrete

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Abstract: With the lack of natural sand and stone resources, machine-made sand will be widely used in the building materials industry. By adjusting the proportion of machine-made sand and river sand, the application of using the machine-made sand in C30 and C50 concrete was explored. The results indicate that the proportion of machine-made sand is 40% in C30 concrete, which makes the concrete show the best performance and the maximum compressive strength. In C50 concrete, as the proportion of machine-made sand increases, the initial dispersion of concrete gradually decreases, the loss of dispersion increases, and the working performance of concrete decreases. It is worth noting that, regardless of the proportion of machine-made sand, the performance of concrete mixed with machine-made sand is higher than that of concrete prepared with pure river sand at 3d, 7d, and 28d.

1. Introduction

As a fine aggregate in commercial concrete, the quality of sand played an important role in the workability, compressive strength, and durability of concrete. With the rapid development of urbanization, real estate, highway, high-speed railway, and other industries, the demand for commercial concrete gradually increases[1]. The lack of sand resources in most areas of China has led to the rapid development of the building materials industry to turn to machine-made sand because of the excessive exploitation of natural sand and the gradual strengthening of environmental protection[2-4]. Compared with natural sand, manufactured sand has the advantages of rich resources, efficient management, controllable quality, and quality assurance.

At present, there are some manufacturers of machine-made sand in Guangdong Province, but these manufacturers have some shortcomings such as immature production process, imperfect production process, uneconomical and environmental protection, which leads to an unreasonable gradation of manufactured sand, high silt content, and high powder content, which limits the application of manufactured sand in concrete[5]. A large number of studies have shown that poor gradation, high silt content, and high powder content of manufactured sand will seriously affect the workability, strength grade, and durability of concrete[6,7]. Although China has issued mandatory standards for sand and stone quality, due to the regional characteristics of sand and gravel aggregate, few of the sand and gravel provided in actual production can fully meet the standard[8]. Most manufacturers adjust the mix proportion design according to the raw materials. It is found that the technology of mixing machine-made sand and river sand at the concrete production end can effectively improve the problems of unreasonable sand gradation, high silt content, and high powder content, which has a positive significance for the improvement of concrete quality. Therefore, for Guangdong Province, systematic
research on the influence of the mixing process of machine-made sand and river sand on the working performance, strength grade, and durability of concrete is helpful to improve the scientificity, efficiency, economy, and quality of concrete in the building materials industry.

Because most of the mixing enterprises are far away from the construction site, commercial concrete needs to spend a certain amount of time in the transportation process. At the same time, there is a certain error between the departure time interval of the mixing enterprise and the pumping time required by the pump truck. Therefore, in the actual production of commercial concrete, it is necessary to consider not only the initial state of concrete but also the decline of concrete performance during long-distance transportation. This experiment is based on the premise of satisfying the best workability of concrete and comparing the concrete with different proportion of manufactured sand. Slump, expansion, and time-lapse loss of concrete are important indexes to measure the working performance of concrete. In order to compare the influence of different proportions of manufactured sand on the workability of concrete, a series of experiments with different proportions of manufactured sand are designed. In this paper, the mixing process of manufactured sand and river sand of C30 and C50 concrete is systematically studied, and a series of scientific experimental data are obtained. The actual production of soil has guiding significance.

2. Experimental

2.1. Test raw materials
Cement (C, Yuexiu brand, P.O 42.5R); Strait sand (S1, river sand with fineness modulus of 2.3 and mud content less than 0.4%); Machine-made sand(S2, machine-made sand with fineness modulus of 2.71 and stone powder content of 5%); Gravel (G, the grain size of 10-20 mm); Fly ash (F, Level II); Slag powder (K, Level S95); Water: tap water meeting the test requirements.

2.2. Performance test method
The concrete test is conducted according to GB/T50080-2016 "Standard Test Methods for Performance of Common Concrete Mixtures" and GB/T 50081-2002 "Standard Test Methods for mechanical properties of Common Concrete". Test the performance of concrete mixtures and hardened concrete. The C30 concrete test mix proportion (kg/m³) was shown in Table 1 and the C50 concrete test mix proportion (kg/m³) was shown in Table 2. Machine-made sand was used to replace river sand with 20%, 40%, 60%, 80%, and 100% of sand mass respectively. The total amount of river sand and machine-made sand in C30 and C50 concrete were 800kg / m³ and 650kg / m³, respectively.

| Table 1. The C30 concrete test mix proportion (kg/m³). |
|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|
| C               | F               | K               | G               | W               |
| 200             | 80              | 80              | 1060            | 160             |

| Table 2. The C50 concrete test mix proportion (kg/m³). |
|-----------------|-----------------|-----------------|-----------------|-----------------|
| C               | F               | K               | G               | W               |
| 305             | 85              | 90              | 1110            | 150             |

3. Experimental results and discussion

3.1. The proportion adjustment of river sand and machine-made sand in C30 concrete
Figure 1. Effect of different proportions of machine-made sand on the dispersion and the slump loss of C30 concrete.

With the increase of the proportion of machine-made sand replacing river sand, the dispersion tends to be first decreasing, then increasing, and finally decreased sharply. When the proportion of machine-made sand is 40%, the dispersion is the best in C30 concrete. Compared with river sand, machine-made sand is rough and multi-angular, which increases the friction between aggregates, and stone powder and mud powder in machine-made sand increase the water demand of concrete. The reason for the increase of dispersion is that with the increase of the proportion of machine-made sand, the filling effect of the micro aggregate of stone powder can meet the requirements of aggregate for slurry and improve the water retention performance of concrete. When the content of machine-made sand is more than 40%, the excessive stone powder will cause the viscosity of concrete paste, and the irregular shape of the machine-made sand increases the friction between aggregates, resulting in the decrease of the concrete expansion rate.

3.2. Effect of different proportions of machine-made sand on compressive strength of C30 concrete

As shown in Figure 2, with the increase of the proportion of machine-made sand replacing river sand, the compressive strength of concrete at 3d, 7d, and 28d tends to be first decreasing, then increasing, and finally decreased. When the proportion of machine-made sand is less than 40%, with the increase of machine-made sand, the filling effect of a small amount of micro aggregate can not improve the edge angle, which leads to the decrease of cementation strength and compressive strength of C30 concrete. When the proportion of machine-made sand is 40%, the joint effect of angularity, stone powder, and mud powder reaches the optimal value. The stone powder plays a filling effect of micro aggregate to meet the demand of slurry, and also improves the interfacial adhesion and the
crystallization degree of hydration products. As the proportion of machine-made sand continues to increase, the excessive stone powder cannot provide cementation, and the increase of mud powder not only affects the normal hydration of cement but also makes a large amount of free water absorbed in the concrete and forms more microcracks inside the concrete, which leads to the decrease of the compressive strength of C30 concrete.

3.3. The proportion adjustment of river sand and machine-made sand in C50 concrete

![Figure 3. Effect of different proportions of machine-made sand on the dispersion and the slump loss of C50 concrete.](image)

It can be seen from Figure 5 that for high-grade concrete, adding a small amount of machine-made sand has little effect on the expansion degree of concrete. With the increase of the proportion of machine-made sand, the dispersion of concrete gradually decreases, and the loss of expansion degree increases with the increase of the proportion of machine-made sand. High-grade concrete has sufficient glue material and abundant grout volume. The increase of stone powder greatly increases the water demand for concrete, which leads to a decrease in concrete expansion. It should be noted that the main minerals of granite are feldspar and quartz, and Ca(OH)2 will be precipitated on the surface of the quartz, and the crystal growth of this phase is faster than that of calcium silicate hydrate, which leads to excessive time loss.

3.4. Effect of different proportions of machine-made sand on compressive strength of C50 concrete

![Figure 4. Effect of different proportions of machine-made sand on compressive strength of C50 concrete.](image)

As shown in Figure 4, the compressive strength of concrete mixed with machine-made sand is greater than that of pure river sand concrete, which shows that the positive effect of manufactured sand is greater than that of the negative effect when the amount of rubber material is sufficient. The reason for
the improvement of concrete strength is that machine-made sand has more grain edges and corners, rough surface, and better adhesion with cement paste.

4. Conclusions

(1) In C30 concrete, adding an appropriate amount of machine-made sand was beneficial to improve the working performance and compressive strength of concrete, and also to improve the quality of concrete. The influence of particle shape, surface roughness, and stone powder content of machine-made sand on concrete had two sides. The silt content will not only increase the storage capacity but also reduce the compressive strength of concrete. By adjusting the proportion of machine-made and river sand and the amount of admixture, the workability of concrete can be optimized, improve the quality of commercial concrete. In C30 concrete, the proportion of machine-made sand was 40%, which made the concrete reach the best workability.

(2) In C50 concrete, the use of manufactured sand should be reduced as much as possible. The addition of machine-made sand has a great influence on the workability of concrete. It was worth noting that the content of stone powder and mud powder had a great influence on the workability of concrete. With the increase of the proportion of machine-made sand, the workability of concrete decreased gradually under the condition of constant mix proportion and admixture.

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