Study on How to Determine the Methylene Blue (MB) Value of Machine-made Sand and Its Effects on Admixture Dosage and Compressive Strength of Concrete

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ABSTRACT: Machine-made sand is a raw material commonly used in concrete production, and its quality has a very obvious effect on the performance of concrete. This paper conducted an experiment to determine the methylene blue (MB) value of machine-made sand, explored the effects of the value changes on the admixture dosage and compressive strength of concrete, and analyzed the mineral components of machine-made sand. The research results show that the mud dosage in machine-made green sand is relatively higher, and the admixture dosage increases along with the increasing of the MB value. The mixing of different types of machine-made sand has a certain effect on the compressive strength, which reaches the peak at a certain ratio.

1. Introduction

In the process of project construction, as an important part of concrete structural materials¹, sandstone plays a decisive role in influencing the quality and durability of the entire project. Under the premise of meeting the performance indicators of building sands, an economical and feasible plan, which not only meets the construction quality requirements, but also effectively controls the production cost, must be selected. In areas lacking natural sand resources, using highly efficient counterattack crushers or impact crushers to make high-quality sand for concrete production and construction is not only feasible, but also conducive to generate overall benefits. In addition, during the use of machine-made sand, researches and experiments can be conducted in the field of building materials to accumulate theoretical experience. Although the firmness of machine-made sand is slightly worse than that of river sand, it still reaches the excellent product quality index level specified in GB/T 14168-1993 standards, and there is no problem in using it in ordinary concrete. However, when used in concrete components that are often subjected to frictional impact, admixtures for concrete must be added². Therefore, in this experiment, we mainly studied the effects of mountain sand with different qualities on the admixture dosage in scenarios where the ratio is different. By comparing multiple groups with the only one variable, we reached the conclusions about the sensitivity of different dosages of mountain sand to the admixture dosage.
After mechanical crushing, screening, and soil removal, rocks, mine tailings, and industrial waste particles\(^3\) with a size of less than 4.75mm are commonly known as artificial sand. Soft rocks and weathered rock particles are not included.

There are 16 main technical indicators of machine-made sand, which are particle gradation, fineness modulus, stone powder dosage, porosity, apparent density, bulk density, methylene blue (MB) value, crushing value index, mica dosage, dosage of light substances, etc. This paper mainly studied how to determine the MB value of machine-made mountain sand\(^4\) and explored the effects of the value on the admixture dosage and compressive strength.

2. Experiment

2.1. Admixtures for Concrete

Details of the admixtures used in this experiment are shown in Table 1:

| Name                                   | Type                  | Manufacturer                                       |
|----------------------------------------|-----------------------|----------------------------------------------------|
| Water-reducing mother liquor (S04)     | Solid dosage: 50%     | KZJ New Materials Group Guizhou Co., Ltd.          |
| Slump retaining agent (S10G)           | Solid dosage: 50%     | KZJ New Materials Group Guizhou Co., Ltd.          |
| Retarder for concrete (H2)             | Food-grade            | KZJ New Materials Group Guizhou Co., Ltd.          |
| Air-entraining agent (Y27)             | Industry-grade        | KZJ New Materials Group Guizhou Co., Ltd.          |
| Water (W)                              | Running water         | KZJ New Materials Group Guizhou Co., Ltd.          |
| Cement (C)                             | P.O 42.5              | Longli Hongshi Cement Co., Ltd.                    |
| Machine-made white sand (S1)           | Fineness modulus: 2.5-3.5 | Guiyang Municipal Construction Group Co., Ltd. |
| Machine-made green sand (S2)           | Fineness modulus: 2.4-3.2 | Ruifeng Commercial Concrete Co., Ltd. |
| Gravel (G)                             | Particle size: 6-32 mm | Guiyang Municipal Construction Group Co., Ltd. |

![White sand (S1)](image1.png) ![Green sand(S2)](image2.png)

Figure 1 Machine-made sand used in this experiment

Details of the main instruments used in the experiments are shown in Table 2:

| Instrument                          | Model   | Main Technical Parameter                                      |
|-------------------------------------|---------|----------------------------------------------------------------|
| Forced single-shaft concrete mixer  | SJD-60  | Mixing capacity: 60L                                           |
| Standard NC curing box for cement   | SHBY-40B| Measurement error of temperature and humidity controllers: ±1°C; Temperature difference inside: ≤1.5°C; Humidity controlled: ≥95% |
Digital pressure testing machine | DY-2000 | Maximum load: 2000KN
Methylene blue tester | JY-3 | Maximum number of rotations: 600; minimum number of rotations: 400; number of impellers: 4

2.2. Admixture ingredients
In order to compare the effect of the MB value of machine-made sand on the admixture dosage with that on the compressive strength of concrete, the same polycarboxylate water-reducer was used during the experiment. The mother liquor of the polycarboxylate water-reducer was produced by KZJ New Materials Group (Guizhou) Co., Ltd. The proportion of the concrete admixtures shown as Table 3.

| No | C (kg) | W (kg) | S1 (kg) | S2 (kg) | G (kg) |
|----|--------|--------|---------|---------|--------|
| 1  | 360    | 165    | 1050    | 0       | 825    |
| 2  | 360    | 165    | 945     | 105     | 825    |
| 3  | 360    | 165    | 840     | 210     | 825    |
| 4  | 360    | 165    | 735     | 315     | 825    |
| 5  | 360    | 165    | 630     | 420     | 825    |
| 6  | 360    | 165    | 525     | 525     | 825    |
| 7  | 360    | 165    | 420     | 630     | 825    |
| 8  | 360    | 165    | 315     | 735     | 825    |
| 9  | 360    | 165    | 210     | 840     | 825    |
| 10 | 360    | 165    | 105     | 945     | 825    |
| 11 | 360    | 165    | 0       | 1050    | 825    |

2.3. MB Value Determination and Concrete Performance Test
The MB value of machine-made sand was determined by using the method specified in GB/T 14684-2011 "Sand for Construction".

The concrete performance test was carried out in accordance with GB/T 50080-2016 "Standard for test method of performance on ordinary fresh concrete", GB/T 50081-2019 "Standard for test methods of concrete physical and mechanical properties" and GB 50107-2010 "Standard for Evaluation of Concrete Compressive Strength". In the test, mix ratios of C30 concrete were used to test the different effects of the MB value on the admixture dosage and compressive strength when proportions of machine-made sand vary. The mix ratios used in the experiment are shown in Table 4.

| No | S1 (kg) | S2 (kg) | Amount of Methylene Blue Solution (ml) | MB Value |
|----|---------|---------|---------------------------------------|----------|
| 1  | 1050    | 0       | 12                                    | 0.60     |
| 2  | 945     | 105     | 15                                    | 0.75     |
| 3  | 840     | 210     | 15                                    | 0.75     |

3. Experiment Results and Analysis

3.1. Determination of the MB Value of Machine-made Sand
The MB value was determined according to the operating procedure of the methylene blue experiment, the measured amount of methylene blue solution used in the experiment are shown in Table 5.
As shown in Table 4 and Table 5, mix ratios were designed based on different proportions of machine-made white sand (S1) and machine-made green sand (S2), and the MB value was then tested for different ratios of machine-made sand. As the proportion of machine-made green sand goes up, the amount of methylene blue solution required for the experiment increases, that is, the MB value increases, the fineness modulus of the two kinds of machine-made sand becomes similar, and the machine-made green sand (S2) contains a higher amount of mud.

3.2. Effects of MB Value on the dosage of Concrete Admixtures

For the convenience of comparison, the expansion degree of C30 trial concrete is uniformly controlled at 580±5mm to compare the admixture dosage, as shown in Table 6 below:

| No. | Dosage (g/15L) | Slump/Expansion (mm/mm) |
|-----|----------------|-------------------------|
| 1   | 99.7           | 220/575                 |
| 2   | 117.2          | 225/580                 |
| 3   | 135.1          | 220/575                 |
| 4   | 137.6          | 230/585                 |
| 5   | 140.1          | 225/580                 |
| 6   | 142.0          | 220/580                 |
| 7   | 144.1          | 220/575                 |
| 8   | 145.9          | 225/585                 |
| 9   | 147.1          | 230/580                 |
| 10  | 148.8          | 225/575                 |
| 11  | 150.3          | 230/580                 |
It can be seen from Figure 2 that with the regular increase in the proportion of machine-made green sand (S2) and the continuous decrease of machine-made white sand (S1), the MB value rises linearly, and the admixture dosage increases logarithmically and gradually slows as the machine-made green sand (S2) continuously replaces the machine-made white sand (S1). This indicates that after the machine-made green sand (S2) becomes the dominant ingredient, the effects of machine-made white sand (S1) on the admixture dosage gradually reduce and the admixture dosage gradually increases. It can be seen from Figure 1 that when the MB value changes between 0.6 and 1.0, it has the largest effects on the admixture dosage and the effects are the same when the value changes between 1.0 and 1.75.

3.3. Effects of MB Value on the Compressive Strength

It can be seen from Figure 3 that when the MB value is about 0.75, the compressive strength of 3d is the highest, and when the MB value is 1.5, compressive strengths of 7d and 28d are the highest. This indicates that when a large amount of machine-made white sand (S1) and a small amount of machine-made green sand (S2) are mixed together, the compressive strength is higher in the early stage; when a small amount of machine-made white sand (S1) and a large amount of machine-made green sand (S2) are mixed together, the compressive strength is higher in the later stage. In the compressive strength test of 3d, the compressive strength first increases along with the increasing of the amount of green sand and later decreases gradually. While in the same test of 7d, the strength
increases along with the increasing of the amount of green sand in the whole process. This indicates that the concrete made by machine-made white sand has a higher compressive strength in the early stage while that made by green sand has a higher compressive strength in the later stage. For 28d, the strength increases all the way throughout the process.

3.4. Component Analysis of Machine-made Sand

The machine-made white sand (S1) and machine-made green sand (S2) used in the above experiment were sent to Guizhou University for component analysis. The analysis results are shown in Table 7.

| Component | Quarz | Montmorillonie | Mia | Hornstoe | Kaolinite | Feldspar | Calcie | Dolomie | Irmore |
|-----------|-------|----------------|-----|----------|-----------|----------|--------|---------|--------|
| S1        | 2.0   | y              | y   | y        | y         | 0.8      | 95.4   | 1.8     | y      |
| S2        | 6.2   | 2.3            | 1.2 | y        | 0.9       | 1.2      | 56.3   | 31.1    | 0.8    |

Note: y indicates fewer amount, which is not taken into calculation.

It can be seen from Table 7 that the main component of machine-made white sand (S1) is calcite (95.4%) with a small amount of dolomite and quartz, while the main component of machine-made white sand (S2) is calcite (56.3%), dolomite (31.1%), and a certain amount of Quartz, montmorillonite, kaolinite and feldspar. These components are usually the main mineral components of clay, which further shows that the mud dosage of machine-made green sand (S2) is higher than that of machine-made white sand (S1). With the increase in the consumed amount of green sand, the amount of concrete admixture absorbed by mud goes up, and the admixture dosage rises as well.

4. Conclusion

(1) When the proportion of machine-made green sand (S2) is regularly being increased and the proportion of machine-made white sand (S1) is continuously being reduced, the value of methylene blue (MB) rises linearly.

(2) When the MB value changes between 0.6 and 1.0, it has the largest effects on admixture dosage.

(3) When the machine-made green sand (S2) becomes the dominant ingredient, the effects of machine-made white sand (S1) on the admixture dosage gradually reduce, and the admixture dosage increases logarithmically and gradually slows as the machine-made green sand (S2) continuously replaces the white sand (S1).

(4) When the MB value is around 0.75, the compressive strength of 3d is the highest, and when the MB value is 1.5, the compressive strength of 7d is the highest.

(5) The compressive strength is higher in the early stage when machine-made white sand (S1) and machine-made green sand (S2) are mixed together. It becomes higher again in the later stage when a small amount of machine-made white sand (S1) and a large amount of machine-made green sand (S2) are mixed together.

(6) With the increasing of the proportion of green sand, the compressive strength of 3d goes up first and then gradually decreases. However, for 7d, the strength increases during the whole test process. For 28d, the strength also gradually becomes higher.

(7) The mud dosage of machine-made green sand (S2) is higher than that of machine-made white sand (S1). With the increase in the amount of concrete admixture absorbed by mud, the admixture dosage gradually rises.

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