Research on the Influence of Different Flocculants on Concrete Performance

Renliang You, Yuetao Qiu, Pan Zhang, Zhifeng Pan
KZJ New Materials Group Co., Ltd. Xiamen 361101, Fujian, China
E-mail: owen@xmabr-kzj.com

Abstract. By adding different types and amounts of flocculants into concrete, the effects of different types and amounts of flocculants on the initial flow performance, slump retention performance and compressive strength of concrete at different ages were studied. The test results show that PAM-3 has the greatest influence on the performance of concrete. When the content of PAM-3 exceeds 0.48g/15L, the compressive strength of concrete will be reduced. When the content of PAM-1 and PAM-2 is less than 0.24g/15L, it has no obvious influence on concrete performance. When PAC content is less than 1.8g/15L, it has no obvious influence on concrete performance. Increasing the amount of concrete admixture can alleviate the adverse effect of flocculant on concrete to a certain extent.

1. Introduction
Concrete is the most widely used and the largest amount of a building material in civil engineering, as an important raw material of concrete sand demand is also very great[1-3]. In recent years, natural sand resources have been unable to meet the demand for construction sand, and it has become a general trend to replace natural sand with machine-made sand[4-6]. Since January 2018, a number of environmental laws and environmental protection schemes have been implemented, which explicitly require sand and gravel plants to strictly prohibit the discharge of waste water and to recycle it. Therefore, a large number of sand making plants add flocculants in the sewage treatment process. The addition of flocculant makes the suspended turbidity in sewage settle quickly and the supernatant can be used for sand making again. The recovered water is continued to be used in the sand washing process. Although the problem of sewage discharge is well solved, there will be residual flocculant in the recovered water, and the amount of residual flocculant will increase due to the repeated use of water. The water containing flocculant residue is used in the production of mechanism sand, so that the produced mechanism sand will inevitably contain a variable amount of flocculant. These flocculants may affect the properties of concrete.

This paper studies the influence of different flocculants on concrete in order to guide the use of such sand in mixing plants.

2. Experimental
2.1. Materials
2.1.1. Cement
Zhangping Hongshi Cement Co., LTD., "Hongshi" brand, 42.5R-grade ordinary Portland cement, its performance indicators are shown in Table 1.

| Fineness/% | Standard consistency water requirement/% | Setting time/min | Initial setting time | Final setting time |
|-----------|------------------------------------------|------------------|---------------------|-------------------|
| 11.4      | 26.8                                     | 185              | 300                 |

2.1.2. Gravel
A certain stone material factory in Xiang’an produces granite crushed stone. The specific performance indicators are shown in Table 2.

| Particle size/mm | Bulk density/(kg/m³) | Mud content/% | Crushed value/% | Needle flake content/% |
|-----------------|----------------------|---------------|-----------------|------------------------|
| 5~31.5          | 1520                 | 1.2           | 8.2             | 7.9                    |

2.1.3. Sand
Class II mechanical sand, produced in a sand factory in Xiamen, the performance indicators are shown in Table 3.

| Fineness modulus | Apparent density/(kg/m³) | Clay lump content/% | Clay content/% |
|-----------------|--------------------------|---------------------|---------------|
| 2.8             | 2640                     | 0                   | 2.5           |

2.1.4. Concrete admixture
Point-400s type concrete admixtures produced by KZJ New Materials Group Co., Ltd., and its evenness indexes are shown in Table 4.

| Solid content/% | Density (g/cm³) | pH |
|-----------------|-----------------|----|
| 10.0            | 1.024           | 5.0|

2.1.5. Flocculant
The flocculants information used in this experiment is shown in Table 5.

| Serial number | Type                                      | Note                        |
|---------------|-------------------------------------------|-----------------------------|
| PAM-1         | Anionic-type polyacrylamide               | Molecular weight 12 million |
| PAM-2         | Nonionic-type polyacrylamide              | Molecular weight 10 million |
| PAM-3         | Cationic-type polyacrylamide              | Molecular weight 10 million |
| PAC           | Polyaluminium chloride                    | Active substance 30%        |

2.2. Experimental method
The mixture ratio of C30 concrete was selected for the experiment, and the experiment was carried out in accordance with GB/T 50080-2016 Experimental method standard for Performance Test Methods of Ordinary Concrete Mixtures. Under the conditions of different types of flocculants and different dosage of flocculants, the changes of concrete initial slump (spreading), concrete slump (spreading) after 1 hour and compressive strength at 3, 7 and 28 days were tested respectively. The concrete mix ratio used in the experiment are shown in Table 6.

Table 6. Concrete mix ratio
3. Experimental results and discussion

3.1. Effect of PAM-1 on concrete performance
Different amounts of PAM-1 were added to the concrete to study the influence of the amount of PAM-1 on the concrete performance. The experimental results are shown in Table 7.

| Serial number | PAM-1 dosage (g/15L) | Dosage of concrete admixture (kg/m³) | TL0/TL1(mm) | TK0/TK1(mm) | Compressive strength /MPa |
|---------------|----------------------|-------------------------------------|--------------|-------------|--------------------------|
|               |                      |                                     |              |             | 3d       | 7d       | 28d      |             |            |            |            |            |
| E001-1        | 0                    | 6                                   | 210/170      | 550/370     | 19.1     | 29.8     | 39.0     |             |            |            |            |            |
| E001-2        | 0.12                 | 6                                   | 210/170      | 570/370     | 19.5     | 30.0     | 39.4     |             |            |            |            |            |
| E001-3        | 0.24                 | 6                                   | 210/170      | 560/370     | 22.2     | 30.2     | 38.8     |             |            |            |            |            |
| E001-4        | 0.48                 | 6                                   | 190/160      | 530/330     | 21.3     | 30.5     | 39.3     |             |            |            |            |            |
| E001-5        | 0.72                 | 6                                   | 190/150      | 510/300     | 22.2     | 31.4     | 40.6     |             |            |            |            |            |
| E001-6        | 0.96                 | 6                                   | 195/125      | 490/-       | 20.1     | 29.0     | 38.5     |             |            |            |            |            |
| E001-7        | 1.20                 | 6                                   | 190/75       | 450/-       | 21.7     | 30.2     | 40.6     |             |            |            |            |            |
| E001-8        | 1.20                 | 7                                   | 190/150      | 510/310     | 21.4     | 30.5     | 41.0     |             |            |            |            |            |

As shown in Table 7, when the dosage of flocculant PAM-1 is 0.24g/15L (i.e. the dosage of flocculant accounts for 1/50,000th of the dosage of sand), the initial slump (spreading) of concrete is not affected. After adding a small amount of PAM-1, the workability is better and the initial concrete spreading increases slightly. When the dosage of the flocculant PAM-1 exceeds 0.48g/15L, with the increase of the dosage of PAM-1, the initial slump (spreading) of concrete begins to decrease, and the slump (spreading) after 1-hour also decreases. By comparing E001-5, E001-7 and E001-8, it is found that by increasing the dosage of concrete admixture, some adverse effects brought by flocculant (PAM-1) can be eliminated. The compressive strength test results of 3-day, 7-day and 28-day concrete showed that the amount of PAM-1 had little influence on the compressive strength of concrete within the scope of the experimental amount.

3.2. Effect of PAM-2 on concrete performance
Different amounts of PAM-2 were added to the concrete to study the influence of the amount of PAM-2 on the concrete performance. The experimental results are shown in Table 8.

| Serial number | PAM-2 dosage (g/15L) | Dosage of concrete admixture (kg/m³) | TL0/TL1(mm) | TK0/TK1(mm) | Compressive strength /MPa |
|---------------|----------------------|-------------------------------------|--------------|-------------|--------------------------|
|               |                      |                                     |              |             | 3d       | 7d       | 28d      |             |            |            |            |            |
| E002-1        | 0                    | 6                                   | 210/205      | 540/415     | 22.6     | 31.8     | 38.4     |             |            |            |            |            |
| E002-2        | 0.12                 | 6                                   | 190/190      | 530/410     | 22.2     | 31.6     | 38.4     |             |            |            |            |            |
| E002-3        | 0.24                 | 6                                   | 195/200      | 515/420     | 22.4     | 32.4     | 39.2     |             |            |            |            |            |
| E002-4        | 0.48                 | 6                                   | 185/185      | 520/355     | 22.8     | 31.0     | 39.2     |             |            |            |            |            |
| E002-5        | 0.72                 | 6                                   | 205/190      | 510/340     | 22.9     | 30.7     | 37.6     |             |            |            |            |            |
As shown in Table 8, when the dosage of flocculant PAM-2 is 0.24g/15L (i.e. the dosage of flocculant accounts for 1/50,000th of the dosage of sand), the initial slump (spreading) of concrete is not affected. When the dosage of the flocculant PAM-2 exceeds 0.48g/15L, with the increase of the dosage of PAM-2, the initial slump (spreading) of concrete begins to decrease, and the slump (spreading) after 1-hour also decreases. By comparing E002-5, E002-7 and E002-8, it is found that by increasing the dosage of concrete admixture, some adverse effects brought by flocculant (PAM-2) can be eliminated. The compressive strength test results of 3-day, 7-day and 28-day concrete showed that the amount of PAM-2 had little influence on the compressive strength of concrete within the scope of the experimental amount.

### 3.3. Effect of PAM-3 on concrete performance

Different amounts of PAM-3 were added to the concrete to study the influence of the amount of PAM-3 on the concrete performance. The experimental results are shown in Table 9.

| The serial number | PAM-3 dosage (g/15L) | Dosage of concrete admixture (kg/m³) | TL0/TL1(mm) | TK0/TK1(mm) | Compressive strength /MPa |
|-------------------|----------------------|-------------------------------------|--------------|--------------|--------------------------|
|                   |                      |                                     |              |              | 3d          | 7d          | 28d         |
| E003-1            | 0                    | 6                                   | 205/205      | 540/415      | 25.8        | 30.9        | 38.6        |
| E003-2            | 0.12                 | 6                                   | 190/190      | 510/320      | 25.2        | 30.5        | 42.1        |
| E003-3            | 0.24                 | 6                                   | 185/170      | 515/320      | 24.9        | 30.4        | 39.2        |
| E003-4            | 0.48                 | 6                                   | 185/105      | 485/-        | 24.4        | 25.3        | 36.1        |
| E003-5            | 0.72                 | 6                                   | 180/80       | 440/-        | 24.0        | 25.5        | 35.1        |
| E003-6            | 0.96                 | 6                                   | 180/40       | 410/-        | 22.4        | 25.8        | 34.0        |
| E003-7            | 0.96                 | 7.2                                 | 190/115      | 490/-        | 22.3        | 23.9        | 34.0        |

As shown in Table 9, when the dosage of flocculant PAM-3 is only 0.12g/15L (that is, the dosage of flocculant accounts for 1/100,000 of the dosage of sand), the initial slump (spreading) of concrete decreases significantly, and the initial slump (spreading) of concrete decreases sharply after 1 hour. In general, with the increase of the dosage of the flocculant PAM-3, the initial concrete slump (spreading) gradually decreases, and the concrete slump (spreading) decreases more obviously after 1 hour. By increasing the dosage of concrete admixture, part of the influence of flocculant (PAM-3) can be eliminated. With the increase of the dosage of the flocculant PAM-3, when the dosage exceeds 1/50000 of the weight of sand, the compressive strength of concrete at 3-day, 7-day and 28-day has a downward trend.

### 3.4. Effect of PAC on concrete performance

Different amounts of PAC were added to the concrete to study the influence of the amount of PAC on the concrete performance. The experimental results are shown in Table 10.

| The serial number | PAC dosage (g/15L) | Dosage of concrete admixture (kg/m³) | TL0/TL1(mm) | TK0/TK1(mm) | Compressive strength /MPa |
|-------------------|--------------------|-------------------------------------|--------------|--------------|--------------------------|
|                   |                    |                                     |              |              | 3d          | 7d          | 28d         |
| E004-1            | 0                  | 6                                   | 205/205      | 540/415      | 25.8        | 30.9        | 38.6        |
| E004-2            | 0.12               | 6                                   | 190/190      | 510/320      | 25.2        | 30.5        | 42.1        |
| E004-3            | 0.24               | 6                                   | 185/170      | 515/320      | 24.9        | 30.4        | 39.2        |
| E004-4            | 0.48               | 6                                   | 185/105      | 485/-        | 24.4        | 25.3        | 36.1        |
| E004-5            | 0.72               | 6                                   | 180/80       | 440/-        | 24.0        | 25.5        | 35.1        |
| E004-6            | 0.96               | 6                                   | 180/40       | 410/-        | 22.4        | 25.8        | 34.0        |
| E004-7            | 0.96               | 7.2                                 | 190/115      | 490/-        | 22.3        | 23.9        | 34.0        |
As shown in Table 10, when the dosage of flocculant PAC is 0.48 g/15L (i.e., the dosage of flocculant is less than two-fifths of the dosage of sand), the initial slump (spreading) of concrete is not affected. When the amount of flocculant PAC exceeds 0.96 g/15L, the initial slump (spreading) of concrete begins to decrease, but there is no significant difference in the slump (spreading) after 1 hour. By comparing E004-5 and E004-8, it is found that some adverse effects caused by PAC can be eliminated by increasing the dosage of concrete admixtures. The compressive strength test results of 3-day, 7-day and 28-day concrete showed that the amount of PAC had little influence on the compressive strength of concrete within the scope of the experimental amount.

4. Conclusions
(1) When the dosage of PAM-1 and PAM-2 is lower than 0.24 g/15L, it has no obvious influence on the initial performance of concrete. If the dosage of flocculant continues to increase, the initial slump (spreading) of concrete will become smaller. The decrease of concrete initial slump will lead to the increase of concrete slump loss. By increasing the dosage of concrete admixture, the influence on concrete flow performance can be reduced. In this experiment, PAM-1 and PAM-2 had no significant influence on the compressive strength of concrete for 3 days, 7 days and 28 days.

(2) The initial fluidity and slump loss of concrete are greatly affected by the addition of PAM-3. When the dosage of PAM-3 exceeds 0.48 g/15L, the compressive strength of concrete will be reduced.

(3) When PAC dosage does not exceed 1.8 g/15L, it has little influence on the initial flow performance and slump loss of concrete. When PAC dosage does not exceed 3.6 g/15L, it has little influence on concrete slump loss. PAC has no obvious influence on compressive strength of concrete within the scope of the experimental dosage.

Acknowledgments
Thanks to Jiayan Zhang and others for their help in the experiment. Thanks to them, my experiment can be successfully completed. Thanks to Zhuojun Jiang for his guidance and help in the preparation of my thesis, which has greatly improved my study, scientific research and thinking. I would like to express my heartfelt thanks and deep respect to them.

References
[1] Wang, Y.F. (2008) Analysis of Application Prospect of Artificial Sand in Premixed Concrete Industry. Ready-Mixed Concrete, (06):46-41.
[2] Hua D.M., Liu X. (2018) Analysis on the Characteristics and Application Prospect of Mechanism Sand Concrete. Development Guide to Building Materials, 16(12):77-79.
[3] Li Z.J., Chui Y.C. (2012) Application Prospect of Mechanism Sand. Communications Science and Technology Heilongjiang, 35(12):56.
[4] Jiang J.P., Gao Z.H., Fan W.X. (2000) Study of Super-high Strength Machine-made Sand High-performance Concrete. Concrete, (04):18-22.
[5] Li F L., Zhu Q. (2010) Strength Development of Concrete with Proto-Machine-Made Sand. Advanced Materials Research, 1033:1479-1482.
[6] Li X., Qin X.Z., Zhang C.X., et al. (2004) Machine-made sand and fine sand in high performance concrete. Concrete, (12):63-65.