Study on the Properties of Gypsum-based Self-leveling Mortar using Molybdenum Tailings

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Abstract. In this paper, the gypsum-based self-leveling mortar is prepared using FGD gypsum-based α-hemihydrate and molybdenum tailings as the binder and aggregate respectively. The effects of different aggregate on fluidity, early and absolute strength are studied. The results indicate molybdenum tailings can replace quartz sand as aggregate to produce self-leveling mortar, and the performance indexes meet the standard requirements of China. The main differences between molybdenum tailings and quartz are the fineness and morphology of particles. Moreover, using molybdenum tailings as aggregate, the early strength is slightly better than that of the ordinary gypsum-based self-leveling mortar.

1. Introduction

In China, with the increase of mineral recourses consumption, a large number of tailings generated from beneficiation progress. Now, tailing disposal is generally directly discharged into tailings reservoir. The approach not only takes up a lot of farmland, but also causes environmental pollution around the tailing reservoir. So, the comprehensive utilization of tailings is one of the most important issues in the fields of mineral resources utilization and environmental protection. There has a successful precedent using tailings as aggregate for preparing different building materials [1-3]. Self-leveling underlayment has been frequently used on a concrete floor in various fields, such as new-building construction and repair work. It gains lots of popularity due to its particular properties [4-5]. It is noted that there is great difference in using different kinds of aggregates compared with the general aggregate such as quartz sand to produce self-leveling mortar. In this paper, a technique has been developed under direction by applying molybdenum tailings as aggregate in self-leveling mortar.

2. Materials

2.1 Chemical composition analysis

Table 1 The XRF analysis of Molybdenum tailings

|     | Al₂O₃ | BaO  | CaO  | Cl   | Fe₂O₃ | K₂O  | MgO  | MoO₃ | Na₂O | P₂O₅ | SO₃  | SiO₂ | TiO₂ |
|-----|-------|------|------|------|-------|------|------|------|------|------|------|------|------|
|     | 14.66 | 0.29 | 1.55 | 0.17 | 3.10  | 0.46 | 0.27 | 2.59 | 0.16 | 1.28 | 65.97 | 0.28 | 0.28 |

Table 2 The XRF analysis of α-high strength gypsum

|     | SO₃  | CaO  | SiO₂ | Al₂O₃ | Fe₂O₃ | Na₂O | K₂O  | Cr₂O₃ | SrO  | Crystal water |
|-----|------|------|------|-------|-------|------|------|-------|------|---------------|
|     | 57.57| 40.31| 1.02 | 0.51  | 0.21  | 0.15 | 0.12 | 0.09  | 0.03 | 5.9           |
As it can be seen from Table 1, the main constituents of molybdenum tailings are SiO$_2$ and Al$_2$O$_3$. They are 65.97% and 14.66% respectively and the total content is upon 80%. The two components are present in the form of soluble salts which can result the phenomenon of efflorescence and affect the adhesive property. The main constituents of FGD gypsum-based α-high strength gypsum are SO$_3$ and CaO (Table 2).

2.2 Mechanical properties
The mechanical properties of α-high strength gypsum are outlined in Table 3. The determination methods used are according to the Chinese professional standard α-high strength gypsum.

| α-gypsum /g | Water reqiiurement | Initial setting time /min | Final setting time /min | 2h Flexural strength /MPa | Absolute dry compressive strength /MPa |
|-------------|---------------------|---------------------------|-------------------------|--------------------------|---------------------------------------|
| 100         | 0.39                | 4                         | 9                       | 6.3                      | 46.31                                 |

2.3 The partial size distribution of materials
As it is shown in Figure 1, FGD gypsum-based α-high strength gypsum has the particle size distribution ranging from 2μm to 30μm and its cumulative distribution of 91% particles are not more than 30μm. Compared with the particle size distribution of natural α-high strength gypsum, the FGD-gypsum based α-high strength gypsum has relatively small particle size and much narrower particle size distribution.

![Figure 1. Particle size distribution of the FGD-gypsum based α-high strength gypsum](image)

As it is shown in Figure 2, molybdenum tailings have the particle size distribution ranging from 10μm to 300μm and their cumulative distribution of 90% particles are not more than 240μm. The D10, D50 and D90 of molybdenum tailings are 9 μm, 90 μm and 238μm respectively. Compared with the particle size distribution of quartz sand, the molybdenum tailings have relatively small particle size and much narrower particle size distribution. As it is shown in Figure 3, the particle size of molybdenum tailings is smaller than the size of quartz sand. The particles of molybdenum tailing are different from quartz sand. Molybdenum tailings have irregular grain morphology, sharp edges and corners, and are easy to be tightly packed form during the progress of hydration and hardening. While the grain morphology of quartz sand is more similar to a small spherical shape, and the interface is smoother, which contributes to the increase of fluidity, but it is difficult to form the close packing and the binding force between aggregate and gelling material will decrease. The microscopic differences of particles between molybdenum tailings and quartz sand affect the mechanical properties of self-leveling mortar. As it is seen in Table 4 and Table 5, when the mixing amount is not more than 45%, the strength of the self-leveling mortar using molybdenum tailings is higher than that using quartz sand.
Figure 2 Particle size distribution of molybdenum tailings

Figure 3. The SEM (×400) of molybdenum tailings (left) and quartz sand (right)

2.4 Phase analysis

Figure 4 The XRDs of α-high strength gypsum (left) and molybdenum tailings (right)

As it is shown in Figure 4, the main phase of FGD gypsum based α-high strength gypsum is hemihydrate. The diffraction angles of the three strong peaks of XRD are 14.75°, 29.70° and 31.86°. The corresponding normalized intensity ratios are 0.89, 1.00, and 0.70, respectively. It indicates the α-high strength gypsum has better crystallization.
The main phases of molybdenum tailings are quartz, analcime and feldspar. The result of XRF analysis indicates the molybdenum tailings have higher insoluble salts content of Na and K which come from feldspar. The insoluble salts of K and Na can’t result in the phenomenon of efflorescence which could affect the bonding strength of the self-leveling mortar.

3. Result and discussion
From Figure 5, it can be seen the standard consistency water demand is slightly decreasing with the increasing content of quartz sand or molybdenum tailings. However, the self-leveling mortar with molybdenum tailings as the aggregate has higher water demand which can reduce the later mechanical strength of the self-leveling mortar. When added the retarder at the same mixing amount, the fluidity loss of self-leveling mortar using molybdenum tailings as aggregate are higher than that using quartz as aggregate (Figure 6).

The mechanical properties of self-leveling mortar with molybdenum tailings and quartz sand as aggregates are shown in Table 4 and Table 5 respectively. As it is shown in Figure 7 and Figure 8, with the increasing of the mixing amount of molybdenum tailings or quartz sand, the flexural strength for 1d and absolute dry compression strength are all decreasing. The strength reduction of self-leveling mortar using molybdenum tailings as the aggregate is higher than that using quartz sand as aggregate. When the aggregate mixing amount added is lower than 45%, the strength for 1d of self-leveling mortar using molybdenum tailings is always 15% higher than that using quartz sand as aggregate. Under the condition of the same mixing amount which is lower than 45%, the aggregate using molybdenum tailings or quartz sand has little effect on the absolute dry compression strength of self-leveling mortar. It indicates the self-leveling mortar using molybdenum tailings can satisfy the demand of Chinese professional standard gypsum-based self-leveling mortar.

Table 4 The properties of self-leveling mortar using molybdenum with different mixing amount

| Content of molybdenum tailings/% | Water demand | Consistency /mm | 20min fluidity /mm | Initial time /min | Final time /min | 1d flexural strength /MPa | Absolute dry compressive strength/MPa |
|---------------------------------|--------------|-----------------|--------------------|------------------|----------------|---------------------------|-------------------------------------|
| 1                               | 30           | 0.248           | 139                | 120              | 33             | 63                        | 2.3                                 |
| 2                               | 35           | 0.254           | 140                | 136              | 32             | 68                        | 2                                   |
| 3                               | 40           | 0.24            | 135                | 110              | 32             | 66                        | 2.3                                 |
| 4                               | 45           | 0.24            | 141                | 131              | 34             | 69                        | 2.1                                 |
| 5                               | 50           | 0.24            | 139                | 133              | 35             | 70                        | 1.7                                 |

Table 5 The properties of self-leveling mortar using quartz sand with different mixing amount

| Content of quartz tailings/% | Water demand | Consistency /mm | 20min fluidity /mm | Initial time /min | Final time /min | 1d flexural strength/MPa | Absolute dry compressive strength/MPa |
|------------------------------|--------------|-----------------|--------------------|------------------|----------------|---------------------------|-------------------------------------|
| 7                            | 30           | 0.23            | 140                | 133              | 34             | 64                        | 2                                   |
| 8                            | 35           | 0.23            | 140                | 137              | 33             | 62                        | 2                                   |
| 9                            | 40           | 0.23            | 139                | 139              | 36             | 64                        | 1.9                                 |
| 10                           | 45           | 0.22            | 143                | 139              | 35             | 63                        | 1.8                                 |
| 11                           | 50           | 0.21            | 140                | 130              | 36             | 63                        | 1.8                                 |

27.49  24.26  24.66  22.53  20.98  29.13  24.22  24.13  23.93  21.27  23.93
4. Conclusions
The work aims to study the possibility of molybdenum tailings as aggregate for the manufacture of self-leveling mortar. Thus an experimental study is carried out to evaluate the fluidity, flexural strength and compressive strength. The results indicate molybdenum tailing particles are different from quartz sand. The differences mainly reflected in the particle size diffraction and morphology. Therefore, the gypsum-based self-leveling mortar using molybdenum tailings as aggregate needs relatively higher water demand and they also exhibit higher mechanical properties. Moreover, the insoluble salts of K and Na in the main phase of molybdenum tailings cannot result in the phenomenon of efflorescence. The range of mixing amount of molybdenum as self-leveling mortar aggregate is not more than 45% and the best amount is 35%. The results of this study indicate molybdenum tailings can replace quartz sand as aggregate for the gypsum-based self-leveling mortar.
All the properties of self-leveling mortar prepared with molybdenum tailings can meet with the requirements of Chinese standard (JC /T 1023-2007) even when the content of molybdenum tailings up to 45%.

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