Research on the Influence of Additive Quantity on Properties of Silica Aerogels/Glazed Hollow Beads Composite Thermal-insulating Mortar

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Abstract. The effects of the content of fly ash, redispersible latex powder and methyl cellulose on the properties of thermal insulation mortar were studied. The results showed that the incorporation of fly ash was beneficial to the mechanical properties and pore structure of hardened paste; redispersible emulsion powder improved the workability of thermal insulation mortar, and enhanced the bonding force between inorganic cementitious material and lightweight aggregate; methyl cellulose significantly reduced the dry density of thermal insulation mortar.

Introduction

Silica aerogel has been known as the lightest and the best thermal insulation material in solid materials all over the world[1], of which more than 90% volume is made up of tiny nanopores. Aerogel has hydrophobic property itself, incomparable superiority and importance among heat insulation materials, which can effectively solve the problem that the traditional thermal insulation mortar has a high thermal conductivity due to a high water absorption rate. Glazed hollow bead is a kind of inorganic light insulation material and it has irregular spherical body, glossy smooth surface and internal porous structure. As a result, it has the advantages of light weight, good insulation properties and ageing resistance[2]. The spherical surface of glazed hollow beads can increase the fluidity of mortar and reduce water consumption at the same time, while its internal porous structure plays a good function of heat preservation and the strength of the particles. Silica aerogel and glazed hollow bead are mixed for the complex aggregate of insulation mortar, which makes up for the disadvantages of the traditional aggregate such as large water absorption rate, poor workability, large dry density, cavity and cracking[3].

Good performance of silica aerogel-glazed hollow beads composite insulation mortar needs excellent admixture as a guarantee. This paper studies on the effects of various additives on silica aerogel-glazed hollow beads composite insulation mortar, in order to further understand the mechanism of admixture and make a better application of insulation mortar in practice engineering.

Experiment

Raw Material

Grade 42.5 ordinary Portland cement from Jiangsu Yangzi Cement Ltd was used, with an apparent density of 3100 kg/m$^3$. Fly ash from Changzhou thermal power plant was considered, with an apparent density of 2500 kg/m$^3$. Silica aerogel was obtained from Guangdong Alison Ltd and glass hollow beads was from Jiangsu Hua Weijia building materials Ltd; Methyl cellulose, namely HPMC 200000s and redispersible emulsion powder, namely INNAPAS 5044N were both from Shanghai Chen Qi Chemical Ltd.

Mix Proportions

Mix proportion design of the thermal insulation mortar follows the Chinese standards GB/T20473—2006. The experiment of content of redispersible emulsion powder as an example, the total volume of the aerogel and glass hollow beads are fixed to 60% and aerogel ratio of composite
aggregate volume is fixed at 35%, where the content of redispersible emulsion powder accounts for 0%, 0.5%, 1.5%, 2% and 4%, respectively. The details of mix proportions are listed in Table 1.

Table 1. Mix proportion of thermal insulation mortar (40mm×40mm×160mm).

<table>
<thead>
<tr>
<th>sample</th>
<th>aerogel(g)</th>
<th>glass hollow beads(g)</th>
<th>cement(g)</th>
<th>fly ash(g)</th>
<th>plasticizer (g)</th>
<th>redispersible emulsion powder (g)</th>
<th>fiber (g)</th>
<th>methyl cellulose (g)</th>
<th>water(g)</th>
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<tr>
<td>1</td>
<td>16.13</td>
<td>29.95</td>
<td>348.06</td>
<td>69.61</td>
<td>12.53</td>
<td>0</td>
<td>1.25</td>
<td>2.51</td>
<td>167.07</td>
</tr>
<tr>
<td>2</td>
<td>16.13</td>
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<td>348.06</td>
<td>69.61</td>
<td>12.53</td>
<td>2.09</td>
<td>1.25</td>
<td>2.51</td>
<td>167.07</td>
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<td>69.61</td>
<td>12.53</td>
<td>6.27</td>
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<td>2.51</td>
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<td>29.95</td>
<td>348.06</td>
<td>69.61</td>
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<td>29.95</td>
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<td>69.61</td>
<td>12.53</td>
<td>16.71</td>
<td>1.25</td>
<td>2.51</td>
<td>167.07</td>
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</table>

Sample Preparation

Aerogel, glass hollow beads, cementitious materials, water and additives were put into the mortar mixer stirring 3 minutes. Plasticizer was used to control the consistency of mortar. The specimen size is 40mm×40mm×160mm, the mortar was put into the curing box(20±2)℃ after mortar was formed. The compressive strength, flexural strength, water absorption and consistency were tested according to the Chinese standards GB/T20473—2006 and JGJ70—2009.

Results and Discussion

Effect of the Fly Ash Content on the Properties of Thermal Insulation Mortar. Adding fly ash to insulation mortar can improve workability and water retention of the mortar due to a large number of glass beads, and also has a better effect on the later strength[4].

![Figure 1](image1.png)  ![Figure 2](image2.png)

Figure 1. Compressive strength varying with fly ash content. Figure 2. Water absorption varying with fly ash content.

The changing trend of 7d and 28d compressive strength varying with fly ash content was shown in Figure 1. As is shown in the 7d compressive strength curve from Figure 1, the appropriate amount of fly ash instead of cement reduced the early strength of the mortar, and the larger the amount of fly ash was, the lower the early strength showed. It can be seen from Figure 1 that the 28d compressive strength of the mortar increased from 6.21MPa to 7.49MPa when the fly ash content changed in the range of 0 to 20% with an increase of 20%, and decreased when the content was more than 20%. It can also be found from Figure 1 that the fly ash was not conducive to the early strength of the insulation mortar, but in favor of the later strength[5]. The changing trend of water absorption varying with fly ash content was shown in Figure 2. As can be seen from Figure 2, with the increasing fly ash content, the water absorption rate of the mortar decreased firstly and then increased, and achieved the minimum of 15.8% when the content of fly ash reached 20%. This is because the incorporation of fly ash reduces the proportion of cement in cementitious material system, and the pozzolanic effect of fly ash needs to be activated in the alkaline environment. In the early period of cement hydration, the active SiO₂ and Al₂O₃ in fly ash can not react with Ca(OH)₂ in the system to produce the hydration products with the gelation due to the absence of alkaline environment, and the inner pore of cement paste is not filled with enough hydration products, which
leads to the decreased 7d compressive strength of mortar[6]. In the later period of cement hydration, the pozzolanic effect of fly ash is gradually played, which results in the increase of 28d compressive strength of mortar. On the other hand, owing to the micro aggregate effect of fly ash[7], the fine particles of fly ash are uniformly distributed in the cement paste and increase the compactness of hardened cement paste, thus reducing the water absorption and increasing the 28d compressive strength of mortar. However, the compressive strength of mortar decreases along with the fly ash content increases because the amount of Ca(OH)$_2$ and hydrated calcium silicate is relatively small, which can not effectively stimulate the potential activity of fly ash. As a result, the internal pore of mortar can not be filled by the hydration products, and the water absorption of mortar increases.

In summary, the mechanical properties and water absorption of the mortar are optimum when the content of fly ash is 20%.

**Effect of the Redispersible Emulsion Powder Content on the Properties of Thermal Insulation Mortar.** Redispersible emulsion powder can be used as the polymer modified part of the mortar system because of its great redispersible property. It also can enhance the flexibility and improve the cohesion and cohesiveness of the mortar[8].

![Figure 3. Consistency varying with redispersible emulsion powder content.](image)

![Figure 4. Strength and ratio of compressive strength to flexural strength varying with redispersible emulsion powder content.](image)

The changing trend of consistency varying with redispersible emulsion powder content was shown in Figure 3. It was found from Figure 3 that with the increase of the amount of powder, the consistency of mortar decreased, because the powder dissolving need water. When the amount of powder was more than 2%, a large number of emulsion films were coated on the surface of the mortar. High viscous emulsion increased the viscosity of mortar system, and the consistency reduced below 70mm.

The changing trend of compressive and flexural strength and the ratio of compressive strength to flexural strength varying with redispersible emulsion powder content was shown in Figure 4. Figure 4 showed that with the increase of the amount of powder, the compressive strength and flexural strength of mortar showed a downward trend, and the flexural strength decreased slightly. The ratio of compressive strength to flexural strength decreased with the increase of the amount of powder and the flexibility of mortar was getting better. This is because the emulsion powder disperses into organic polymer emulsion when they are brought into contact with water. The cement hardens due to absorbing the water in emulsion after mixing with cement mortar. Because of the water loss, the flexible polymer becomes an elastic film with bonding and continuity. It runs through the cement hardened body and it is firmly bonded into a strong elastic waterproof layer[9]. Based on this principle, the flexibility of the mortar is improved with the increase of the content of emulsion powder. Thus, to some extent, the compressive strength and flexural strength of mortar decreases.

Considering the consistency and workability of mortar, the content of redispersible emulsion powder should not exceed 2% cementitious material content; From the ratio of compressive strength to flexural strength curve we can see that, with the increasing powder content, the ratio of compressive strength to flexural strength decreases significantly when the powder content is in the...
range of 0~0.5% and 1.5%~2%. This shows that the adding of powder does significantly improve the flexibility of the mortar and it also sharply changes when the powder content is in the range of 1.5%~2%. Therefore, the optimal powder content range is 1.5%~2%. Considering the performance and cost of mortar, the optimal powder content is 1.5% cementitious material content.

Effect of the Methyl Cellulose Content on the Properties of Thermal Insulation Mortar. Methyl cellulose can increase the viscosity of the slurry, so as to maintain water and increase the role of adhesion\[10\]. In practical applications, appropriate amount of methyl cellulose should be added to optimize the formulation.

The changing trend of dry density varying with methyl cellulose content was shown in Figure 5. Figure 5 showed that with the increasing methyl cellulose content, the dry density of thermal insulation mortar decreased continuously. The dry density decreased slowly when the content was in the range of 0.2%~0.6% while the dry density decreased sharply when the content was in the range of 0~0.2% and 0.6%~0.8%. This is mainly caused by the air entraining effect of methyl cellulose. The larger the content of methyl cellulose is, the more gas is introduced and the lower the dry density will be.

The changing trend of compressive and flexural strength varying with methyl cellulose content was shown in Figure 6. It can be seen from Figure 6 that methyl cellulose had a significant effect on the strength of mortar. The compressive strength and flexural strength showed an increasing trend when the content was 0.2%~0.8%, and when the content was 0.8%, the compressive strength and flexural strength reached the maximum value of 7.78MPa and 1.34MPa, respectively. This is due to the strong water retaining effect of methyl cellulose. When the methyl cellulose is added into the thermal insulation mortar, the fluidity of the mortar increases and the uniformity is enhanced, and as a result, cementitious material slurry in mortar enwraps glass hollow beads and aerogel more fully. With the working performance improving, the mortar block gets denser, and the strength of mortar will enhance.

It can also be found from Figure 6 that with the increasing methyl cellulose content, the increase of the strength slowed down. This is because with the increasing methyl cellulose content, the more the gas is introduced\[11\], the lower the strength of mortar shows, and the lower the solubility of methyl cellulose will be. In summary, the content of methyl cellulose should not exceed 0.8%, and the optimal content is 0.6%.

Conclusions
The addition of fly ash is not conducive to the development of mechanical strength and pore structure at the early stage, but shows the advantages at the later stage. The mechanical properties and water absorption of the mortar are optimized when the content of fly ash is 20%.

The addition of redispersible latex powder can significantly improve the workability and flexibility of thermal insulation mortar. The optimal content range of powder is 1.5%~2%, and
taking the mortar performance and the cost into consideration, the optimum content of powder is 1.5% of cementitious materials content.

Methyl cellulose can effectively improve the workability and reduce the dry density of the mortar. The content of methyl cellulose should not exceed 0.8% and the optimum content is 0.6%.

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References