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Experimental Study on Structure and Property of Chemical Building Materials Based on SEM Analysis Technology

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Chemical building material has become the fourth largest building material after wood, cement and steel. With the advantages of low energy consumption, environmental protection, low cost, good stability, toughening and strengthening, etc., it has been applied in more fields. In this paper, by taking the material systems of building plastics, building coatings, building waterproofs, and thermal insulation material as the objects of study, SEM technology was adopted to study their microstructures and properties. The study found that the incorporation of mineral materials can improve the properties of building materials in different degrees, and the calcium carbonate can be well combined with the building plastic door and window materials; the combination of kaolin, mica, barium sulfate, and wollastonite with waterproof coatings endows the waterproof coating with good overall performance; illite particles and the waterproof material matrix are ideally cemented, with fuzzy interface, and the overall morphology is presented in the felsitic texture; the interface of vitrified microbeads thermal insulation mortar is not obvious, indicating better thermal insulation effect.

1. Introduction

In recent years, with the demand for building materials increasing, various synthetic polymer resins and building chemicals have become more widely used in doors and windows, pipes, decoration, building waterproofing, and thermal insulation etc. (Shcherban et al., 2014). Chemical building materials have become the fourth largest building material after steel, wood and cement, and are increasingly replacing traditional building materials (Möser, 2011, Jannica et al., 2012). It's the new building material based on synthetic polymer materials and building chemicals, including building plastics, building coatings, and building thermal insulation (Lei et al., 2017, Zorin et al., 2018). The production and use of chemical building materials have the advantages of energy saving, environmental protection, and batch production. According to incomplete statistics, in the winter, the energy consumption of polyethylene plastic windows in northern China is only 26% to 28% of that of steel windows (Lu et al., 2012).

In the broad sense, chemical building materials refer not only to organically synthesized composite materials, but the incorporation of mineral materials also has a great influence on the performance and quality of chemical materials (Giro-Paloma et al., 2015, Qiu et al., 2017). The development of mineral materials is the driving force for the development of chemical building materials. The research and development of mineral materials also results from the promotion of chemical building materials (Hellmich et al., 2009). Mineral materials play an increasing role in chemical building materials, improving dimensional stability, temperature-sensitive property, processability and workability, and also enhancing its function of thermal insulation, reinforcing and toughening (Lu and Wang, 2011, Chabriac et al., 2016). At present, the wide application of structural mineral materials, functional mineral materials and nano-mineral materials has promoted the development of chemical building materials (Schmidt et al., 2013). The current research mainly focuses on the mechanics and durability of chemical building materials, and little research has been done on their microstructure (Bera et al., 2011). Therefore, in this paper, by taking the building plastics, building coatings, building waterproof, and thermal insulation materials system as objects of study, SEM technology was adopted to study their microstructure and properties.

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2. Research on microstructure and properties of chemical building materials system

2.1 Research on microstructure and properties of building plastics system

The most widely used plastic products in the building field are plastic pipes and plastic doors and windows, and both have a considerable production scale (Su et al., 2012). Plastic pipes have been used since the 1970s and developed in the last decade or so. In 2012, the market share of plastic doors and windows exceeded by 50% (Ng et al., 2014). Fig.1 shows the outputs of China's plastic window and door profiles from 2008 to 2017, showing the increasing trend year by year. By 2016, the content of plastic window and door profiles in China has exceeded 5 million tons. For the plastic door and window profiles based on polyvinyl chloride polymer materials, the rigidity and durability can be improved by incorporating calcium carbonate. At present, China's rigid PVC plastic doors and windows has used a large number of specially processed light calcium carbonate or active heavy calcium carbonate. Fig.2 shows the SEM image of calcium carbonate used in plastic door and window profiles, and Fig.2 (a) (b) shows those for light calcium carbonate and active calcium carbonate, respectively. It can be seen that there is no significant difference in the microstructure, but at the same magnification, the big difference exists in the particle size of aggregation.

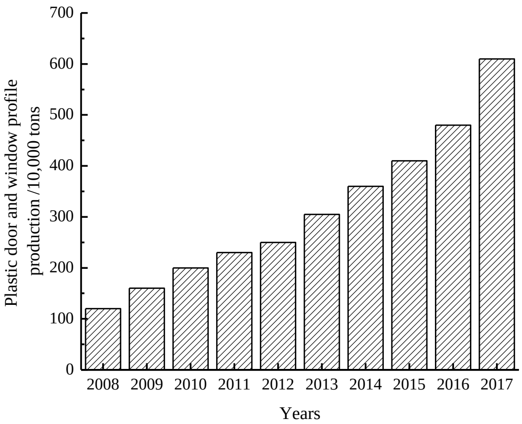

Figure 1: Plastic window and door profile output chart in China from 2008 to 2017

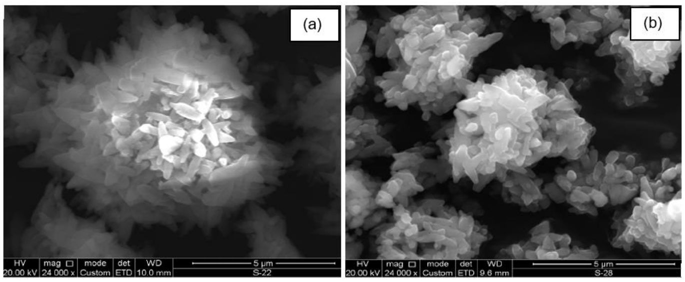

Figure 2: SEM photograph of calcium carbonate used in plastic window profiles (a) Light calcium carbonate; (b) Active calcium carbonate

2.2 Microstructure and properties of building coatings system

Building coatings are generally used for the exterior wall, interior wall, ceiling, and toilet etc. They are composed of base stock, fillers and pigments, dispersion media and additives, for the protection of wall structure and beautification. Building coatings have the advantages of rich colours, good decorative effect, light weight, safe use, low engineering cost, easy maintenance and updating, and diverse functions etc. Fig.3 shows the output of building coatings from 2008 to 2017 in China in the greatly increasing trend year by year, with the demand for building coatings continuously increasing. The mineral materials can improve the water resistance, dispersibility, stability, and aging resistance of building coatings. The fillers for building coating are generally all kinds of mineral materials such as Kaolin, mica, barium sulfate, talc and wollastonite. Fig.4 shows SEM images of building coatings for external walls, where the fillers of the images are kaolin, mica, barium sulfate, talcum powder and Wollastonite, clearly indicating that the interface between the matrix and the filler is clear for talcum powder without ideal cementation, while the particles of the remaining four fillers are well cemented with the matrix.

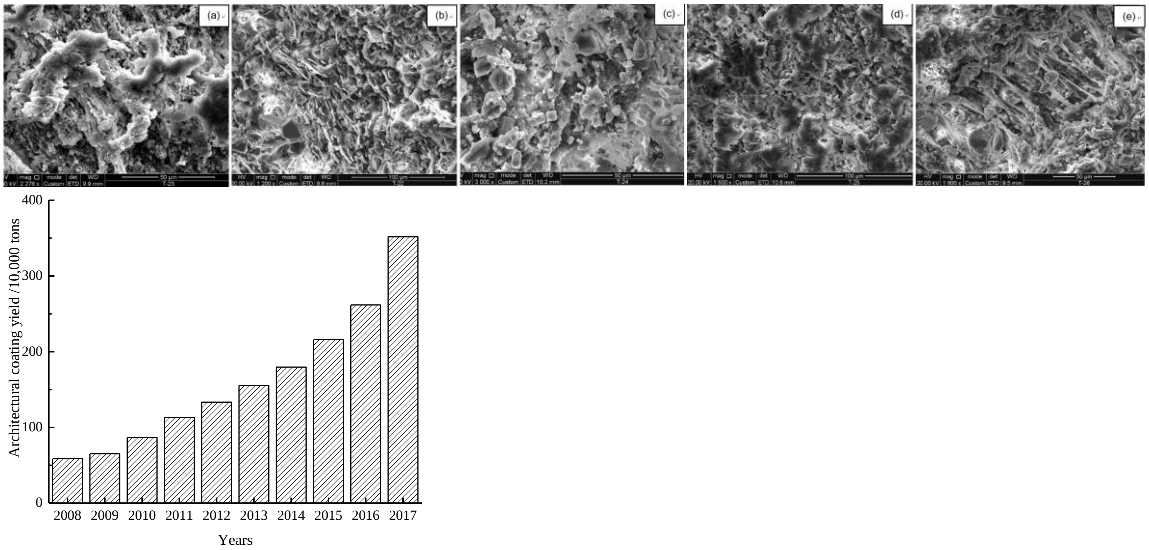

Figure 3: Building coatings output chart in China from 2008-2017 (a) Calcined kaolin; (b) Mica; (c) Barium sulfate; (d) Talcum powder; (e) Wollastonite

2.3 Microstructure and properties of chemical building waterproof material system

2.3.1 Role of mineral materials in building waterproof materials

Water-proof, moisture-proof, seepage-proof and leak-proof are the key to improve the durability and lifespan of buildings. The selection of building waterproof materials is also an important part for protecting building components from being eroded. Emulsified bitumen waterproof coating, neoprene bitumen waterproof coating, polymer waterproofing membrane, and various polymer waterproof coatings are commonly used materials for building waterproof in China. For both traditional asphalt waterproof material or current organic polymer building waterproof material, they're inseparable from the incorporation of mineral materials in the process of production and application. The main role of mineral materials in building waterproof materials is to increase, reinforce, and improve the temperature sensitivity of waterproof material. The incorporated mineral materials such as bentonite, illite, etc. can not only reduce the production cost of the waterproof material, but also improve the compactness and durability of the waterproof coating, thereby improving its resistance to penetration.

2.3.2 Microstructure and properties of building waterproof material system

The new type of polymer building waterproof material generally uses talcum powder, bentonite, illite, etc. as fillers, and talc is mostly used in modified bitumen waterproof membrane. Fig.4 shows the SEM image of talcum powder modified bitumen waterproof membrane, where the polyester is also incorporated besides the talc in Fig.4 (b). From Fig.4 (a), it can be seen that the talc particles and bituminous are better cemented. From Fig. 4(b), the modified bituminous material and the polyester tire base have good fibre cementation, with fuzzy interface, and the cross-section of the sample shows a linear gel-like structure.

Fig.5 shows the bentonite water-stop. It can be seen from Fig.5 (a) that the bentonite particles are loose and the surface of the particles is curved. Fig.5(b) shows the SEM image after water absorption; its volume expands after washing and the layer spacing changes accordingly. Fig. 6a shows the straight polymer waterproof coating, and the micro-cracks are obviously seen on the surface. Fig.5(b) depicts the microstructure of the waterproof coating system added with illite; the illite particles and the waterproof material matrix are cemented well together with fuzzy interface, and the overall appearance is presented in the felsitic structure.

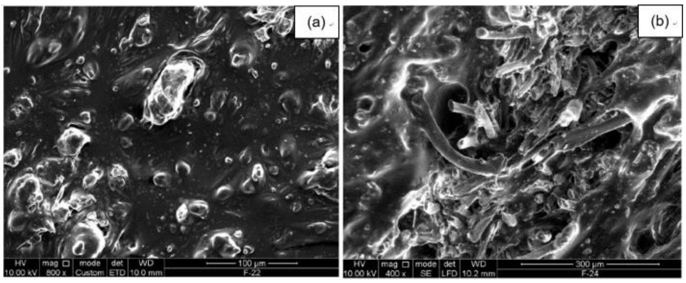

Figure 4: SEM photograph of talc modified asphalt waterproof membrane (a) Asphalt+stone powder-1 (b) Asphalt +stone powder-1+polyester tire

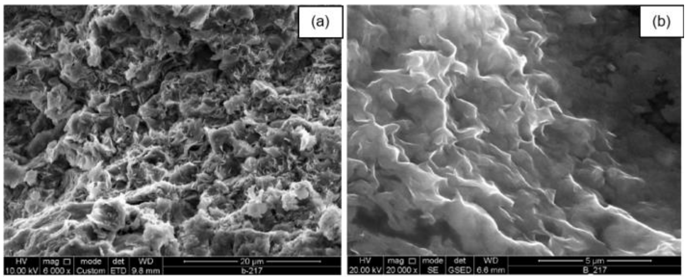

Figure 5: SEM photograph of waterstop belt added bentonite (a) Bentonite before water absorption (b) Bentonite after water absorption

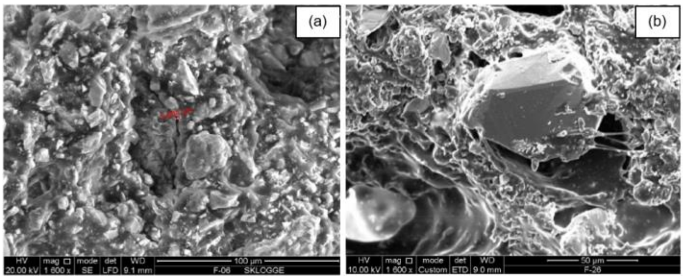

Figure 6: SEM photograph of adding Illite waterproof coating system (a) Polymer waterproof coating (b) Add Illite polymer waterproof coating

2.4 Microstructure and properties of chemical building thermal insulation material system

2.4.1 Role of mineral materials in building thermal insulation materials

Exterior walls, roofs, doors and windows of building are the main parts for heat loss. The primary task of building insulation materials is to save energy. According to incomplete statistics, the use of one ton of insulation materials in the building can save 3 tons of standard coal per year. The energy-saving benefit of materials in full life circle is nearly 10 times the production cost of materials. In terms of different applications, thermal insulation materials can be divided into high-temperature, mid-low-temperature and low-temperature materials. At present, the commonly used thermal insulation materials for building wall are mineral wool and products, EPS expanded polystyrene board thin plaster, rubber powder polystyrene particles, and vitrified microbeads. The incorporation of mineral materials can improve the insulation properties of thermal insulation materials, e.g., adding the sepiolite, expanded perlite, etc. can form microporous coatings in the material, which can provide thermal insulation and thermal insulation.

2.4.2 Microstructure and properties of building thermal insulation material

Glass beads have the advantages of high strength, long service life, and fire prevention, etc. It is a new type of lightweight inorganic thermal insulation material, which has better insulation effect than organic thermal insulation materials. Fig.7 shows SEM images of expanded perlite and vitrified microspheres, where Fig.7 (a) is the expanded perlite with irregular granules, Fig.7 (b) is the vitrified microsphere with irregular spherical granules; both s expanded perlite and vitrified microspheres are in a honeycomb structure. In Fig.7(c), the surface of the expanded perlite is presented in the vitreous structure, while in Fig.7(d), the vitreous cell shell of the vitrified microbead is thick. Fig. 8 shows SEM images of thermal insulation mortar made of polyphenylene granules and vitrified microbeads. Both images show a honeycomb-like microporous structure. The interface of vitrified microbead thermal insulation mortar is not obvious, indicating better insulation performance; there is a clear interface between the powdered polystyrene particles and the mortar, indicating polarity differences.

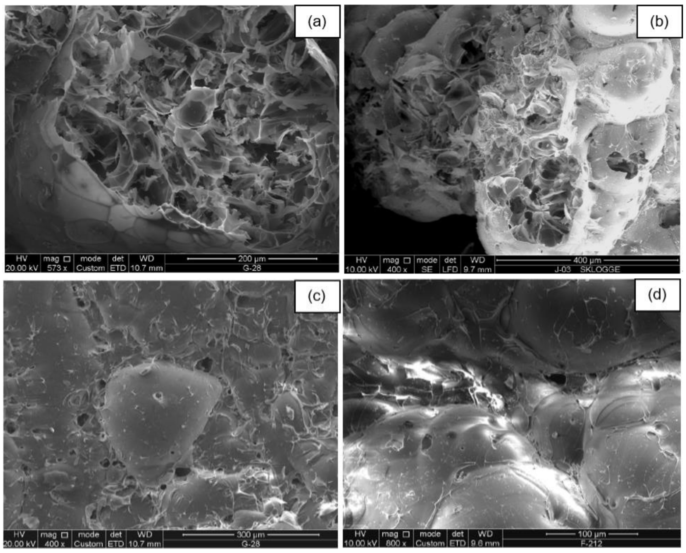

Figure 7: SEM photograph of expanded perlite and glass beads (a) Expanded perlite; (b) Glass beads; (c) Shell surface of expanded perlite; (d) Shell surface of glass beads

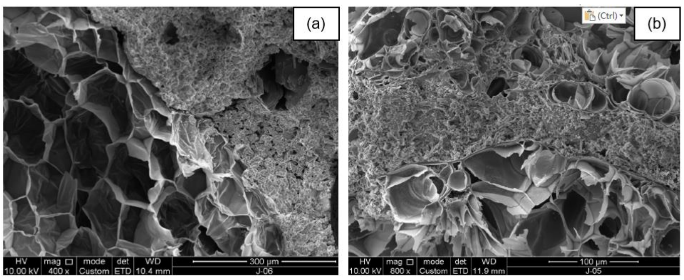

Figure 8: SEM photograph of polystyrene foam plastics granule and vitrified beads (a) Polystyrene foam plastics (b) Vitrified microbeads

3. Conclusions

In this paper, by taking the materials systems of building plastics, building coatings, building waterproofing and thermal insulation as object of study, SEM technology was adopted to study of their microstructure and properties. The specific conclusions are as follows:

(1) In the building plastics material system, light calcium carbonate or active heavy calcium carbonate does not show significant differences in the microstructure of plastic door and window profiles.

(2) In building coatings material system, there is a clear interface between the talc filler and the matrix, with unideal cementation; kaolin, mica, barium sulfate and wollastonite all show good adhesion properties.

(3) In the building waterproof material system, the surface of the pure polymer waterproof coating exhibits micro-cracks, while the waterproof material added with the illite particles is ideally cemented, the interface is blurred, and the overall appearance exhibits the felsitic texture.

In the building thermal insulation materials, the expanded perlite and vitrified microspheres are in a honeycomb structure. The interface of the vitrified microbead thermal insulation mortar is not obvious, indicating better thermal insulation effect; the interface between the powdered polystyrene particles and the mortar is obvious interfaces, showing the polarity differences.

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