Resource Utilization of Solid Wastes from Industry and Mining Industry in the Building Materials Field

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Abstract. With the development of the country, the production of industry and mining is received widespread attention. However, during actual production, solid wastes appear frequently, and there is no efficient way to deal with them comprehensively, which leads to serious pollution to the ecological environment. This paper mainly expounds the sources, characteristics and application and prospect of industrial and mining wastes in building materials. Converting solid wastes into building materials can economize natural resource and ease the problem of resource exhaustion. It turns waste into treasure, turns harm into the benefit and generates huge economic benefits, which is also the comprehensive utilization of solid wastes and a critical way to sustainable development.

1. Introduction
With the development of society, the amount of solid wastes is increasing continuously. It has caused environmental pollution, economic, social and environmental burdens seriously. How to deal with solid wastes and utilize them comprehensively has been a general trend [1]. The so-called solid wastes usually include the solid and gunk that has been discarded in the production and our living and the solid particle that has been separated from the exhaust gas and wastewater [2]. Almost the methods used for dealing with solid wastes are landfill and incineration [3, 4], of which there is still a large part of solid wastes stacked in open-air land, which pollutes our environment and damages our bodies seriously. On the other hand, with the rapid development of urbanization in our country, the demand for building material has increased dramatically. Converting solid wastes into building materials [5] can solve this problem effectively and the recyclable and high-valued application will come true. In industrial production, the main solid wastes include slag waste, steel slag waste, and red mud waste [6]. Converting them to building materials can decline the environmental pollution and alleviate the problem of resource shortage.

2. Typical solid wastes suitable for building materials field
The materials for building field are inorganic materials, the form of it is mainly aggregate and binder. The solid wastes with these features all can be considered as the building materials to take full advantage [7]. This part of solid wastes includes mining solid waste and industrial solid waste.

2.1. Mining solid waste
Most mining waste comes from coal waste, waste rock, and tailings produced by mining and dressing [8]. A large amount of waste appears during mining, which includes the covered rock and low-grade ores. Tailings are fine powder wastes with various size between coarse sand and ultra-fine sand, which
are discharged in the process of mining. The composition of tailings depends on mineral resources and the way of ore dressing. Most coal waste is coal gangue, the elements are Si, Al, Fe, Ca and sulfur oxides [9]. Table 1 is the chemical composition of some mining wastes. We can see that this composition is similar that used in the building materials field. So it can be used to produce building materials after innocent treatment.

| Name of waste            | SiO$_2$ | Al$_2$O$_3$ | Fe$_2$O$_3$ | CaO  | MgO  | SO$_3$ | TiO$_2$ | K$_2$O | Na$_2$O |
|--------------------------|---------|-------------|-------------|------|------|--------|---------|--------|---------|
| Coal gangue              | 54.61   | 18.88       | 5.70        | 0.65 | 1.05 | -      | -       | -      | -       |
| Gold mine tailings       | 70.52   | 5.01        | 12.62       | 3.70 | 1.20 | 3.60   | -       | -      | -       |
| Pyrite tailings          | 39.32   | 32.87       | 6.22        | 1.26 | 0.83 | 11.75  | 5.34    | -      | -       |
| Iron tailings            | 73.41   | 7.34        | 3.55        | 7.05 | 2.93 | 0.06   | 0.17    | 2.05   | 1.44    |
| Copper tailings          | 71.10   | 13.20       | 4.90        | 1.10 | 2.10 | -      | -       | 3.30   | 0.30    |
| Gypsum tailings          | 31.26   | 9.25        | 3.26        | 15.78| 4.06 | 17.23  | -       | 2.31   | 1.08    |

2.2. Industrial solid wastes

The industrial solid wastes are produced by various industrial sectors [10], mainly include coal gangue produced by the coal industry, fly ash and slag from pulverized coal combustion boilers in fuel power plants and urban central heating systems, blast furnace slag and steel slag produced in ferrous metallurgy industry, ferrous metallurgical slag and red mud, chemical gypsum and iron sulfide slag produced in the process of chemical industry and other industrial production and slag from burning boilers [11], etc. Industrial solid wastes are a resource which can be utilized. The phase composition of most industrial solid wastes is relatively stable. Its chemical composition is similar with building materials, as can be seen in Table 2, it has potential activity and is suitable for building materials. From the perspective of chemical composition, most industrial wastes can be used as the materials for wall except some poisonous waste. The chemical composition of coal gangue, fly ash and slag is similar to that of clay, so these wastes are often used for road construction, production of sintered brick, production of concrete products, masonry mortar materials, raw materials of glass-ceramics and other light aggregates.

| Name of waste            | SiO$_2$ | Al$_2$O$_3$ | Fe$_2$O$_3$ | CaO  | MgO  | SO$_3$ | TiO$_2$ | K$_2$O | Na$_2$O | P$_2$O$_5$ |
|--------------------------|---------|-------------|-------------|------|------|--------|---------|--------|---------|-------------|
| Fly ash                  | 52.11   | 26.30       | 8.73        | 5.66 | 1.52 | -      | -       | -      | 2.99    | -           |
| Copper slag              | 28.92   | 6.40        | 59.65       | 2.72 | 3.68 | -      | -       | -      | -       | -           |
| Chromium slag            | 43.20   | 27.20       | 6.80        | 12.00| 9.40 | -      | -       | -      | -       | -           |
| Blast furnace slag       | 25.40   | 6.15        | 0.5-1.0     | 35.45| 2.15 | 0.5-1.5| -       | -      | -       | -           |
| Sulfur slag              | 50.17   | 8.81        | 25.92       | 2.64 | 1.82 | 5.06   | -       | -      | -       | -           |
| Phosphogypsum            | -       | 0.42        | 0.56        | 34.15| 0.52 | 45.58  | -       | -      | -       | P$_2$O$_5$ 1.71 |
| Desulphurization gypsum  | 3.26    | 1.90        | 0.97        | 31.93| 40.09| 0.13   | 0.05    | -      | -       | -           |

3. Application of solid wastes in building materials

In the process of our industrial development, the management of solid wastes has been widely concerned. For some solid wastes that cannot be eliminated completely, we can utilize them comprehensively as building materials, broaden the using way of construction resources, and then, improve the application effect.

3.1. Industrial solid wastes

Coal gangue is the rock that pressed between coal seams, is the waste discharged in the process of coal mining and dressing. The annual discharge amount of coal gangue during coal mining in China is more than 100 million tons, more than half of them are not be used effectively. The disposal and application of coal gangue are paid more and more attention, especially after the 1980s, its application in the field of building materials has become a trend, and the range of application has expanded widely.
The main products are coal gangue sintered brick, coal gangue light aggregate and cement mixture gangue block [12]. What’s more, we can use coal gangue to produce cement and high silicon gangue crystallized glass products. Figure 1 shows the hollow brick and solid brick fired by coal gangue.

Figure 1. Gangue bricks.

3.2. Construction materials from industrial wastes

The comprehensive utilization of industrial solid wastes has been paid more and more attention in the world. Many countries are using industrial wastes as a new resource. They reduce the exploitation of natural resources and solve the pollution of industrial solid wastes by comprehensive utilization. The following are applications of some common industrial solid wastes in the field of building materials.

(1) Fly ash

Fly ash [13] is the industrial residue discharged from coal-fired power plants. Fly ash has wide application methods in the building materials field. The use of fly ash to produce building materials has a long history abroad. In developed countries, fly ash is used in highway embankment, highway, airport and some large projects [14]. In China, since the comprehensive utilization of fly ash was studied in the 1950s, the utilization of fly ash mainly includes building materials, backfill, landfill surface, soil improver, subgrade reinforcement materials, subgrade materials, fly ash cement, mud wall, cement packing [15], etc. What’s more, in recent years, the research and utilization of fly ash have expanded greatly, such as in plastic, thermal insulation materials, soil magnetic compound fertilizer, environmental decontamination, and other aspects have been studied and made progress. In addition, fly ash can also be made into fly ash mineral wool, glass-ceramics, new cementitious materials, gypsum products. With the development of nanotechnology and nanomaterials, a new type of fly ash spheres with ultra-fine hollow microspheres has been added as fillers for some products in recent years, which brings in big profits.

(2) Desulfurization gypsum

Desulfurization gypsum [16] is the byproduct of flue gas desulfurization in power plants. Desulfurization process in power plants is a technology which removes sulfur dioxide from flue gas by lime-limestone. This technique involves grinding lime-limestone into a slurry. The SO2-containing flue gas after dust removal is passed through a slurry scrubber to remove SO2. Lime slurry reacts with SO2 to produce calcium sulfate and calcium sulfite. CaSO3 is oxidized to CaSO4 and then get industrial byproduct gypsum, it is called desulfurization gypsum, which is widely used in various industrials such as building materials field. The meaning of its processing and utilization is very important. It not only promotes the further development of national environmental protection circular economy effectively but also reduces the amount of the mining of mineral gypsum and protects the environment. Gypsum powder is one of the five gel materials, which plays an important role in the national economy. It is widely used in building materials, industrial molds and art models, chemical industry, agriculture, food processing, and medical hairdressing. The difference between desulphurization gypsum powder and ordinary gypsum powder lies in the difference in physical composition, desulphurization gypsum powder contains SiO2, NaCl, CaCO3, CaSO3, CaCl3, and MgCl2 [17]. Compared with other gypsum powders, desulfurization gypsum powder has the characteristics of renewable, small particle size, stable composition, less harmful impurities, and high purity.

(3) Metallurgical slag

The kinds of metallurgical solid wastes are various and the amount is too large. Different metallurgical solid wastes have different characters, but they do serious damage to the environment as same. Slag, steel slag, and iron alloy slag are the wastes residue discharged from metallurgical
industry such as smelting iron and steel-making [18]. It also includes slag discharged from other metallurgical industries, for instance, red mud is the slag of preparing alumina industry. The main component of metallurgical slag is silicate and aluminate, which has some activity. In building materials industry, they can be blended with cement clinker and gypsum to make cement; excellent concrete can be made from metallurgical slag with proper activator; heavy slag with good safety can be used as aggregate and road material instead of gravel after broken and graded. Now they have been widely used in highways, bridges, airports, industrial and civil buildings. Red mud can be used in different ways according to its different composition, such as produce cement, plastic filler and new materials for wall [19].

4. Conclusion
Application of industrial and mining solid wastes in building materials field can improve the situation, high consumption in the traditional building materials industry. It can also save resources and protect the environment. Using more building materials can reduce lots of solid wastes and turn "waste" into wealth, which has obvious social, economic and ecological benefits. Now, comprehensive utilization of industrial solid wastes still can be expanded and improved in range, technology and form, which must truly follow the path of sustainable development in the future.

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