

THE HIGH-TECH RESEARCH PROCESS OF INDUSTRIAL SOLID WASTE IN CHINA

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Abstract

In this paper, the present status of the industrial waste, development foundation, and research progress of high technology are discussed based on the author's experience on the development of industrial waste. The important academic and utility values are presented.

1. Introduction

With the expansion of production scale in modern society, the contradiction between the human beings' needs and the environment becomes more and more acute. This leads to the huge burden in energy, natural resources and environmental pollution. All of these have threatened mankind's subsistence and development.

Material is the physical base and the premise of society development and it is the milestone of mankind advance, too. It creates the material civilization and improves the living condition, but it also accelerates energy consuming and environmental pollution. So the ecological degree of the material's whole life periodicity is an indication that can evaluate the environmental quality.

2. Industrial Solid Waste—Renewable Resource

Based on the national medium-term and long-term technology development outline, the renewable resource is defined as a kind of resource emerged in the process of society production, circulation and consumption, lost their original use value, being stored in many forms, but the useful value can be extracted through different processing methods.

According to the present status of the industrial solid waste in China, mineral tailings, fly ash and coal gangue are the three main industrial solid wastes. The chemical compositions (shown in Table 1) were SiO_2 , Al_2O_3 , Fe_2O_3 and some impurities.

Table 1: Chemical composition of mineral tailings, fly ash, and coal gangue

	SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	Other	Ignition loss
Iron tailing	73.27	4.07	11.60	3.04	4.22	2.1	2.18
Fly ash	50.6	27.2	7.0	2.8	1.2	2.1	8.2
Coal gangue	53.16	15.53	7.43	4.14	0.97	/	16.30

Notes: The mineral tailings data come from AnShan in LiaoNing province. The coal gangue data come from XinWen in ShanDong province. The fly ash data are the national average.

According to the phase diagrams, these industrial wastes belong to SiO_2 - Al_2O_3 -X system. If the appropriate components are added, a series of materials will be developed, such as SiO_2 - Al_2O_3 -CaO system, and SiO_2 - Al_2O_3 -MgO system.

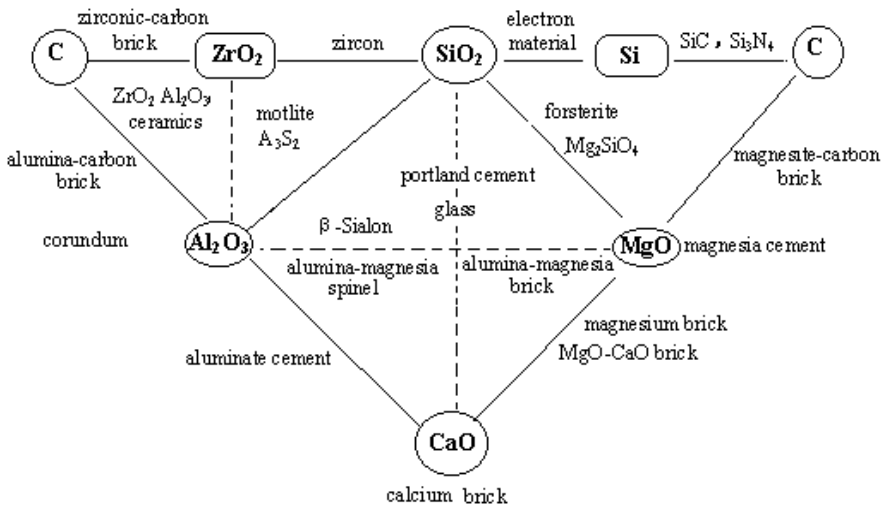


Fig. 1: Derivative diagram of $\text{SiO}_2\text{-Al}_2\text{O}_3\text{-X}$ phase diagram

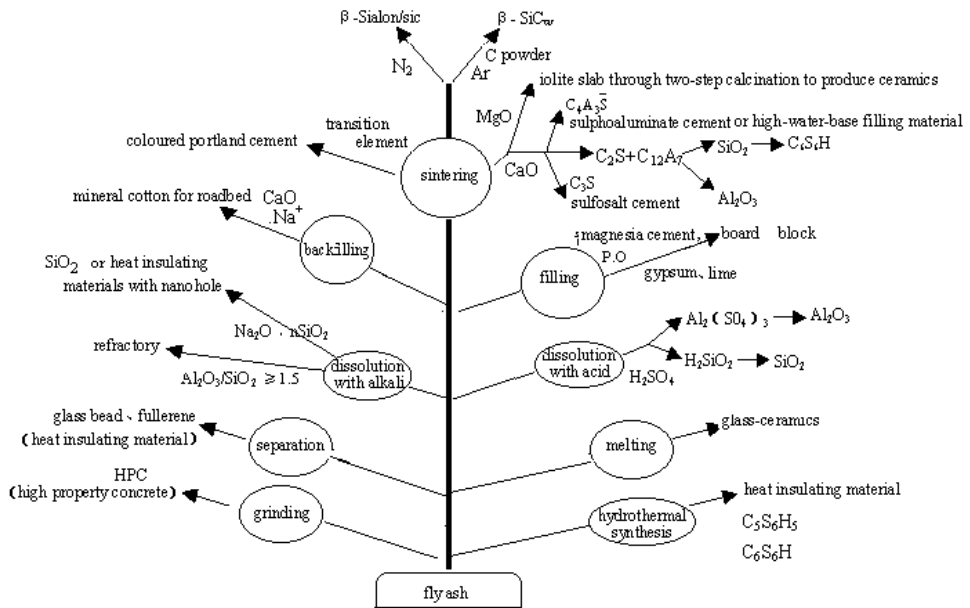


Fig. 2: Fly ash development tree derivation

Fig. 1 is derived from $\text{SiO}_2\text{-Al}_2\text{O}_3\text{-X}$ phase diagram. It is obvious that a series of high-tech products can be developed. It involves glass, ceramics, cement, refractory, wall materials, heat insulating materials, function material, etc. Fig. 2 is the tree derivation of fly ash development. And the tailing has a similar development trend to fly ash. From Fig.2, we can see that the materials, developed by using fly ash, involve almost all the building materials.

3. The High-Tech Research Process

3.1. Micro-crystal glass [1]

Micro-crystal glass has the advantages of mechanical performance, corrosion resistant ability, resistance to abrasion, decorative property, which are also the good attributes of glass and ceramic. Building micro-crystal glass, made by industrial waste, has varies impurity and are often used as building materials.

According to the mineral compositions of these industrial wastes, $\text{SiO}_2\text{-Al}_2\text{O}_3\text{-MgO}$, $\text{SiO}_2\text{-Al}_2\text{O}_3\text{-ZnO}$ or $\text{SiO}_2\text{-Al}_2\text{O}_3\text{-LiO}_2$ system can be chosen to composite the basic glass, and the proper nucleating agent should be chosen, such as TiO_2 , ZnO , LiO_2 , CaF_2 , NaF , etc. In general, there are three production modes, i.e., sintering process, rolling process and floating process.

At present, there are 14 factories product glass-ceramics with raw materials as copper tailings, kaolin clay and sand of weathering in China.

3.2. Metakaolin cement [2]

Metakaolin Cement, named by Professor Wang Lijiu, has a major mineral composition of metakaolin. Others also named it as soil polymer or Pyrament (alkali agitated pozzolana cement trass gel material). Using the kaolin ($\text{Al}_2\text{O}_3\cdot 2\text{SiO}_2\cdot 2\text{H}_2\text{O-AS}_2\text{H}_2$) as the raw material, it forms anhydrous aluminosilicate after dehydration at the right temperature ($600\text{-}900^\circ$), i.e, metakaolin ($\text{Al}_2\text{O}_3\cdot 2\text{SiO}_2\text{-AS}_2$), one kind of artificial volcanic ash material with high reactivity. After being stimulated by alkali or sulphate,

these binding materials can form the hydration products with the composition and structure, which are similar to the hydration products of portland cement. Metakaolin can also react with calcium hydroxide (CH) and water. Adding it into cement can greatly improve certain properties of the cement.

The study of mechanics property indicates the MK's contribution to concrete strength. Similar to zeolite powder, mixing MK into the concrete or test mortars will make steady growth of later time strength, and the MK's contribution to concrete strength will catch up with or even exceed zeolite powder. Wild et al. believed that this is due to three causes: filling effect (the most directly one), accelerating the cement hydration (happening in the first 24 hours), and the volcanic ash gelatinization (When the content of MK varies from 5%-30%, the effect can last for 7 to 14 days at most.) .The experiment of DING Tao et al. indicates that mixing the MK into the portland cement solely would improve the compressive strength for 10 MPa[3]. Qian Xiaolian and Li Zongjin found that mixing 10%-15% MK into the concrete would improve its properties: tensile strength, compressive strength, bending strength and even impact toughness to certain extent [4].

Because adding MK will greatly affect and improve the pore structure, it has been reported that, with the addition of MK, the capillary porosity volume will decrease, while just the porosity whose diameter is 0.05-10 μm can increase the penetrability. So it can increase the concrete's resistance to the erosive solution and ion diffusion, the freezing resistance will be improved, as well. Gruber's studies showed that the high reactive metakaolin (HRM) can improve the concrete durability conspicuously. Mixing 8% and 12% HRM into concrete, the chlorine ion diffusion coefficient is obviously lower than that of the reference block. The study of Khatib and Wild indicated that the sample with 15% MK could show better resistance to sulfate [5]. Walter's research showed that the concrete sample with MK can effectively restrain the alkali-aggregate reaction. The concrete with 10%-15% MK almost has no cracking and surface damage [6]. Kostuch found that the expansion as the result of alkali-aggregate reaction had disappeared in concrete that has 15% MK added.

In U.S.A, a high strength and quick setting cement which is stimulated by alkali has been developed in 1987, i.e., Pyrament. By using this kind of cement, the compressive strength of the concrete can reach 18 MPa in 4 hours and 82.8 MPa in a month [7]. In Finland, “F binding materials” was produced by using the alkali activator ($\text{NaOH}+\text{Na}_2\text{CO}_3$) and lignosulfonic acid [8]. In Japan, the metakaolin is also used for the preparation of binding materials.

3.3. Compound partition plate

In China, the using of vitrified bond bricks has a history of over 2,000 years. But according to the statistics, throughout the country, 80-100 units of fields have been destroyed to product bricks and such power-wasting manufacture makes the total coal used in chamotte production and heating amounts to 1,500,000,000 tons per annum. It is stipulated in Chinese State Department [1999] No. 72 File: “Since Jun 1, 2000, to Jun 30, 2003, solid chamottes are forbidden to use in 160 large and medium coastal cities.” But the problem of the chamottes’ substitutes has not been solved.

As usual, it is facile to use concrete hollow blocks as chamotte substitute, but it has many defects: the large shear strength and dry shrinkage cause walling cracks; the 3-cm wall thickness causes erosion and leakage of rain; at the same time, it’s not easy to achieve insulating, either internal or external; and also, the tailor-made “paving cement apparatus” in construction makes the masonry complex. So the concrete hollow blocks are not popular till now.

Fly ash wall is made of 70% fly ash, 18% pearlite flour, and 12% gelatinization materials. It can be made into $3000\times 600\times 90$ mm internal or external wall plates, and plates with $7\Phi 50$ reinforcing steel of the same size. Its qualities are well conformity with Chinese Construction Industry Trade Standards: bend load 0.45 kN/m^2 , single-point load $> 0.8 \text{ kN}$, coefficient of heat conductivity $0.38 \text{ w/(m}\cdot\text{k)}$, sound insulation 39 db (one layer), 45 db (double layer).

3.4. Joint product method of coal-fired power and cement production

Coal plays an important roll in our nation's development, but it also causes heavy pollution during its production and using. In China, over 80% of coal is used to burn directly, and 1/3 of the production is used in coal-fired power. So the research and development of high efficiency clean burning have a very important reality mean to our nation.

On the other side, our nation's cement annual yield amounts to 6,000,000,000 tons, amounting to 1/3 of the world's gross output value. The cement production costs a lot of crude materials, including clay and lime rock, and the two are both non-renewable resources. The widely use of clay destroyed our land resources seriously; the mining of lime rock destroyed the terrains, landforms and vegetation, and during the production CO₂ is let out. Our electric industry lets out billions of tons of fly ash every year, in 2000, the discharge quantity adds up to 1,600,000,000 tons.

The chemical constitution of coal power's burned remains is about the same to clay's, so it is significance to combine the power generation with cement production. During the generation, adding in crude materials such as calcareous, and letting them react with burned remains can get clinkers, that is to say, the power generation can be directly abrasives into powder as cement.

Adding fertilizer can increase the burning efficiency of coal power to pledge normal production. Its combustion action is that: lower the burning temperature; improve the combustibility; reduce pollution. The application of mineralizer is to lower the synthetic temperature of clinkers, and make the minerals react at lower temperature.

This method has many advantages:

- It solved the problem of acid rain, and SO_x can react with lime into cement additive CaSO₄.
- It can make full use of the remaining energy of generation, saving crude materials.

- It reduces the pollution of fly ash, since the remains can be made into cement directly, heaps can be called off to save land, and avoid the damage of land resources.

The chemical constitution of output cement is C_2S ($2Ca \cdot SiO_2$), it reduces the discharge quantity of CO_2 and the greenhouse effect. Since cement production and power generation both pollute the environment, making them into one can reduce the pollution greatly.

Combining two processes into one, avoids replication of constructing generation station and cement factory, as result, the investment was reduced and the input-output ratio was increased. This process simplifies the cement production technique, and abrasives the crude materials before power generation. The two processes take place at the same time, saving time.

3.5. Construction formwork technique [9]

Concrete is the most popular construction material in the world. But the settlement and removal of forms in construction waste a lot of manpower, materials and funds; at the same time, the heat preservation of concrete still can't be achieved. From 1960s to 1970s, some skills, such as large type formworks and slip forms were tried in use, but were not popular since the high costs and complex technique. Light bricks were used as substitute of chamotte, but still no widely used because of its poor durability and shrink resistance.

These years, our nation's walling production and construction technique adheres to the principle of low cost, energy-saving, environment protecting, less pollution and easy construction, to develop new walling materials, but still hasn't any breakthrough until now.

Construction formwork is a brand-new concrete construction technique, which provides construction of bearing walls and heat preservation. The key technique is construction formwork, which made up of snakeskin meshes, stiffening rib, zigzag loop and benzene plate, as Fig. 3 shows.

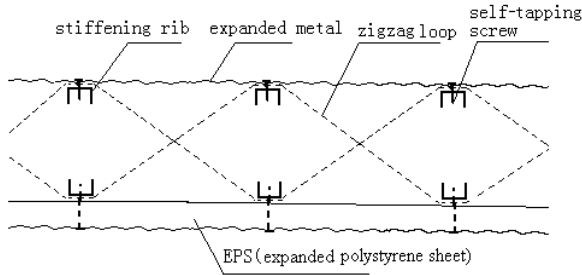


Fig. 3: Conformation of formwork

The formworks are manufactured in factories and packed on-the-spot, pouring in concrete can get formwork concrete. The technique constructs easy, densified by itself without vibration, and has little noise pollution, constructs fast, safe and civilized. The structure has good earthquake resistance and can be filled with many industry wastes such as fly ash, gangue, and tailing. The Construction Formwork Concrete Structure Technique Regulation DB21/1210-2001 chiefly written by Professor Wang, has been put into use since April 1, 2001.

Since its defects that rust-eaten of zigzag loops, durability of the whole structure, the irrationality of formwork structure which will affect the joint construction and the hardness of steel distribution inside meshes, the structure only suits for constructions under multistory. Professor Wang has invented new generation of formworks, especially suits for under multistory, constructs more easily, more safety.

3.6. Super nanometer-hole heat insulator [10, 11]

The super heat-insulating material is the heat insulator which coefficient of heat conductivity is lower than that of non-convection air in certain condition. Because the free paths of the main constitutions –oxygen and nitrogen –are both about 70 nm, only when most of hole size is less than 50 nm can avoid internal convection. In addition, the largest material bulk density should be less than 171 kg/m^3 .

By now, all the nm-hole heat insulators all use SO₂ aerogel as the carrier of nm-hole TEOS is widely used as the main crude material of SiO₂ aerogel. Because of the high cost of TEOS, it's important to find its substitute. Since the pureness of construction insulating materials is not very critical, certain industry wastes can be used as TEOS's substitute.

The process flow is making wastes into water-glass, because its particle phase is some Si-O net structure site in metastable state, and the size range belongs to colloid particle size range. Water-glass will turn into hydrogel by adding in sodium fluosilicate, then let gas instead water in the position during desiccation can get nm-hole aerogel. This gel must be modified because of its low strength and ductility. Usually, fiber is added in order to strengthen it.

4. Summary and Conclusions

The first part of this paper shows the situation of industry wastes in brief. The second part is the theoretical basis of industry wastes research and development. The last part introduces the developments of high-technical research of industry wastes, most of them are latest achievements and patents of the author himself, and also represent present level of our nation's utilization research of industry wastes.

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