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ORIGINAL ARTICLE

New technology and application of brick making with coal fly ash

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Abstract China has ranked first in the coal fly ash emission in the world. The multipurpose use of the fly ash from power plant waste is always an important topic for the Chinese environmental protection, which has drawn the concern of the government, scientific research departments, manufacturing enterprises and industry experts. This paper introduces an experimental research on how to recycle fly ash effectively, a kind of new technology of making bricks by which fly ash content could be amounted to 50–80 %. The article introduces raw materials of fly ash brick, production process and key control points. It introduces how to change the technical parameters of the existing brick-making mechanical device, optimize the parameters combination and improve the device performance. High-content fly ash bricks are manufactured, which selects wet fly ash from power plants, adding aggregate with reasonable ratio and additives with reasonable dosage, and do the experimental research on manufactured products for properties, production technology and selection about technology parameters of production equipment. All indexes of strength grade, freezing-thawing resisting, and other standards of the studied bricks reached the national standards for building materials industry.

Keywords Bricks and building blocks · Experimental research · Fly ash · New technique

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Introduction

Environmental value is the people's cognition on belief, attitude, rational consideration and value of the environment. In 1995 O. Brien and Guerrier pointed that environmental value is advisory and supportive activities of environmental concern and responsibility [1]. With the transformation of social formation, human's value judgment on the natural environment is changed. "we can say that the natural environment is the carrier of value" [2]. And this kind of value could be understood and recognized by mankind.

Coal fly ash from power plants around the world hoards in every corner of the earth, which pollutes the environment and damages cultivated land. In production process of large-scale power plant, coal fly ash is produced in large amounts. The coal fly ash is piled up. It has polluted the environment, destroying cultivated land. Globally, coal-fired power generation has produced billions of tons of fly ash waste over the past centuries, with annual production now at about 800 million tons. Construction industry that comprehensively utilizes resource, especially fly ash and industrial solid waste, is the most effective and the largest amount realm. For example, the amount of fly ash produced at the power plants in Turkey is about 10 million tons per year. Only a small portion of fly ash is used in construction materials [3]. The research on effective use of coal fly ash has very important significance for protecting the environment and developing circular economy.

Since wide-scale coal firing for power generation began in the 1920s, many millions of tons of ash and related by-products have been generated. The current annual production of coal ash world-wide is estimated around 600 million tones, fly ash constituting about 500 million tones at 75–80 % of the total ash produced [4]. The amount of coal waste (fly ash), released by factories and the thermal power plants has been increasing throughout the world, and the disposal of the large amount of fly ash has become a serious environmental problem [5].

Investigation turns out coal slack is one of the largest industrial waste residues. Dregs poured out of industrial boilers are piled like hills in many places. It not only takes up quantities of farmland and land, but also causes serious environmental pollution. In a medium-sized city, the coal fly ash emitted from power plants amounts to more than 800,000 tons every year, piling at the feet of mountains and wild fields, polluting environment, underground water, soil, cultivated lands [6].

Fly ash is pulverized coal thermal power plant boiler, an industrial waste residue excluded. As early as 1914, in the United States, Anon did discover oxides in fly ash, which was similar to a study on "Volcanic ash characteristics". In fact, comprehensive utilization of fly ash can be traced back to 1920, after the transformation of large-scale boiler plants [7]. But the real attention drawn to the problem of fly ash was at the end of World War II, especially after the outbreak of oil crisis at the end of the Cold War, resulting in an accelerated shift to coal in many countries as the main fuel source for power plants. This lead to large number of ash emissions, which in turn further promoted the attention of comprehensive utilization of fly ash. So in some industrialized countries, the comprehensive utilization of fly ash gradually formed a new industry.

For example, most unweathered fly ash, especially those coming from the subbituminous and lignite coals of the western US is high in harmful elements of constituents and usually will cause high soil salinity. The accumulation of B, Mo, Se, and soluble salts in fly ash-amended soils appear to be the most serious constraints associated with land application of fly ash to soil [8].

Taking Anshan as another example, it is a city in Liaoning Province of China, where steel and power generations are leading industries. During production of mining and the process of electric power generation, a great deal of coal gangue and fly ash are produced. It is forbidden to discharge or dump industrial waste residues, urban refuse or other wastes into any water body in China. Fly ash is stored at Hei Niu Zhuang ash field, Mayitun ash field of East Anshan, San Ye base ash field, Xiwei ore ash field and Angang ash field in and around the city, respectively. There are more than a total of 7 million tons fly ash has been stored, nearly 2.6 million square meters land area is covered because of its large quantity of emission, with low availability and serious pollution. In order to protect the environment, the fly ash has been buried in ground or enclosed by ways of digging holes and damming [6].

The technology for making bricks with fly ash is always the project of study for experts on building materials, and the research on brick-making technology with high-content fly ash has been a difficult issue which experts for building materials want to conquer. How to make bricks out of industrial waste, how to comprehensively reuse fly ash in large quantities have become the focus. Relevant experts and enterprises around the world have engaged in the research work with development of fly ash products. Brick building using fly ash has gained more and more attention. Therefore, it is very important to devote to the research on the use of fly ash and industrial waste residue in the building block production process and you can have good economic and social benefits.

There was no special application, which will be the solution to reduce the increasing high amounts of fly ash. For an effective solution, the most reasonable way to recycle fly ash will be application in construction and building materials industry [9]. China has ranked first in the fly ash emission throughout the world. The multipurpose use of the fly ash from power plant waste is always an important topic for the Chinese environmental protection, which has drawn the concern of the government, scientific research departments, manufacturing enterprises and industry experts. However, due to the technical causes from such as mechanical equipment and productive technologies, there are some problems with the quality of most fly ash products, e.g., freeze–thaw, layering, and so on. It has become one hot study for related enterprises, scientific research departments and industry experts how to overcome the weaknesses of the present block-making machines and further enhance the utilization of the industrial waste residue such as fly ash in order to produce construction products which have satisfied various technical properties.

The disposal of fly ash from coal-fired power stations causes significant economic and environmental problems. A relatively small percentage of the material finds application as an ingredient in cement and other construction products, but the vast majority of the material generated each year is held in ash dams or similar dumps. This unproductive use of land and the associated long-term financial burden of maintenance have led to realization that alternative uses for fly ash as a value-added product beyond incorporation in construction materials are needed [10].

At present, some wall experts and brick-making enterprises which produce clay bricks, sand-lime bricks and fly ash bricks have made some achievements in research on how to use the fly ash in manufacturing building wall, but utilization rate of fly ash was only 5–20 %, and the use of additives was increased, production costs for manufacturing enterprises were barely reduced [11].

This paper introduces an experimental investigation about fly ash being reused effectively, presents a kind of new technology for building brick making, with which fly ash content in brick may reach 50–80 %, and practice and theory supports are provided for the development and production of high-content fly ash brick, which fly ash content is more than 50 %. The wall body products mainly include: bricks, building sheets and building blocks, and brick is a kind of building material products. It has thousands of years of history as conventional wall material in China. Thus, wall body products can consume a lot of fly ash, and the cost of brick-making enterprises can be greatly reduced. The efficient reuse of fly ash from coal boilers and power plants has vital significance in protecting the environment, benefiting descendants and developing of a circular economy.

Materials and methods

The present study focuses on existing practices related to the reuse of fly ash and identifies new potential uses. The results presented here showed new possibilities for this waste reuse in a short-term, in a wide range of fields, resulting in great advantages in waste minimization as well as resources conservation [12].

Test site: a brick plant in Changchun City, Jilin Province, China, used as the test site.

Raw materials

- Coal fly ash: fine and wet fly ash from Anshan Power Plant, it was deposited at Mayitun, and was level 3 ash, the chemical composition see Table 1. Fine and wet fly ash was covered with canvas, and was carried to the site by truck. This was achieved using fly ash drier dryer, fly ash was baked for semi-dry state, in waiting for the experiments to come to fruition. Moreover, different people might hold different points of view. Quite a few people maintained that TCLP test was needed in this research; others, nevertheless, for its alkaline features, additives and cementing material showed a strong fixing capacity for heavy metals after fly ash was packed by the United States Environmental Protection Agency's Toxicity Characteristic Leaching Procedure (TCLP), so TCLP test was not needed in this research. I was in favor of the latter opinion.
- Content of aggregate: natural sand, gravel, industrial waste or bigger grain size fly ash
- Cement: Grade 42.5 ordinary Portland cement
- Additive: fly ash additive which was researched and manufactured by CEC Environmental Protection Science and Technology Development Liaoning Co., Ltd.

Introduction of the ratio of raw materials

Main materials including fly ash, aggregate and additives were prepared in certain weight proportion.

Ratio of raw materials mass for fly ash brick

- Fly ash: 50–80 %;
- Cement: 8–13 %;
- Aggregate: 15–35 %;
- Additive: 0.03–0.05 %.

Ratio of materials mass for color fly ash brick

When products for decoration were produced, the process for stone powder should be started.

- Fly ash: 70–75 %;
- Stone powder and gravel for Chromatic adornment (diameter 3–5 mm): 10–15 %;
- Cement (Grade 42.5): 15–20 %;
- Additive: 0.05–0.08 %.

Experimental equipment and production process

Main equipments

Forming machine (H-240, Korea) included hydraulic device, control and operator's desk, chained conveyor and some molds, and the motor power was 36.25 KW, vibration

Table 1 Chemical composition of coal fly ash

Composition	SiO_2	Al_2O_3	Fe_2O_3	CaO	Na_2O	SO_3	K_2O	MgO
Content (%)	53.7	27.6	6.2	3.2	0.8	0.3	1.76	1.6

Moisture content: 0.17 % loss on ignition (Σ): 3.3 %

frequency was 6000–8000 revolutions per minute, and the press force was greater than 60 tons.

Mixer rolling machine (CKS-1500-1, China), the motor power was 22 KW.

The vibration frequency of the presently used forming machines in China is mostly 3500–5000 revolutions per minute, while the press force was about 30 tons. It was designed for production of clay bricks or silicate brick. There were no professional machines and equipments for making fly ash bricks in China.

H-240 forming machine was selected as equipment for the project, the vibration frequency of the forming machines was 6000–8000 revolutions per minute, the press force from 30 to 60 tons and then to 80 tons, and the amplitudes 2–4 mm, and the raw materials would be added as aggregates and additives at reasonable ratio. As a result, the fly ash content in the building block could reach 50–80 %. By comparing and optimizing various combinations of mechanical technology parameters, the bibulous rate, intensity level and freeze–thaw resistance, etc., had achieved relevant national industry standards for building materials from observing, analyzing, researching and testing its function, process and work situation, and so on.

On the basis of all the common kinds of production equipment system for building materials manufacturing, importance should be attached to the following two aspects: one was the mode of stirring mixing (mixer), and the other was the technical requirements for the forming machine. The main machine of the forming equipment was mainly for vibration assisted by pressing. According to the mechanical principles and machine design handbook, we theoretically analyzed the combinations of the technical parameters, optimized the design and turned it out into a test model prototype machine [6]. It was required for the trial produced products that the pass rate, considering compactedness, size deviation, formed condition and weight, etc., of each single block product, should be greater than 98 %, and these products should be sent for testing at the State Silicate Products Quality Supervision Center for Building Materials Industry (please see Table 2).

Technological requirements

First, we put together fly ash, cement and aggregate according to mixing ratio and then rolled and mixed it for 3 min. Secondly, added a small amount of water in the fly ash additives, diluted and stirred well, and put it into the mixture to stir even. For different products, particles degrees (size of aggregates) used for slag and chemical composition of coal fly ash were different, and different technology formula should be used. Thirdly, when the process of production and operation was underway, the mixture of fly ash should be in semi-dry state.

The manufactured samples

See Table 2 for the manufactured samples.

Test products were maintained under atmospheric pressure steam curing in curing room, and the temperature was between 40 and 80 °C for 4–5 h. The test products were pushed to the yard for preservation in natural conditions; it could reach the standard compressive strength 28 days later. As time went on, its strength enhanced obviously, and this was one of the important features of this technology products.

Results

Performance indicators of the manufactured samples

For example, the size of the manufactured samples (fly ash standard brick) was 240 × 115 × 53, the manufactured samples and performance indices see Table 3.

There is an explanation in the "Experiments" described here.

> Flexural strength: flexural strength is an object's ability to bend without obtaining any major deformities.
> Compressive strength: compressive strength is a measure of a material's ability to withstand compressive forces, where it is squeezed laterally.
> Frost resistance: the tolerances of extremely low temperature. It is known as hardiness or frost resistance.
> Drying shrinkage: loss of water held in gel spores that causes the change in volume. It is a function of the fineness and gel.
> Carbonization coefficient: the probability model of the coefficient on carbonization speed in the carbonization experiential formula is established on the test data.

Indices and inspection of products quality

Fly ash standard bricks were formed by aggregate with the strength grade 42.5 ordinary Portland cement, industry waste residues or thick coal fly ash, mixed with a small amount of fly ash additives, by the process of ingredients measuring, rolling, stirring, vibration forming and atmospheric steam curing.

The ratio of the raw materials was cement 8–12 %, coal ash 60–80 %, aggregate 15–35 %, fly ash additive 0.03–0.08 %. The specifications size of test product was 240 × 115 × 53 (mm). Tested by the State Silicate

Table 2 Chart of samples

Type of brick manufactured	Specification (mm)	Quantity of one-step molding (piece)	Quantity of manufacture (piece)	Quantity of inspection (piece)	Quantity of per cubic meter (piece/m^3)
Fly ash standard brick	240 × 115 × 90	8	160	160	402
	240 × 115 × 53	16	128	128	684
Fly ash color adornment brick	240 × 115 × 53	16	128	128	684
Fly ash color ground brick	300 × 300 × 53	6	90	90	39
The fly ash load-bearing hollow bricks	90 × 390 × 190	5	50	50	150
	150 × 390 × 190	3	30	30	90
	190 × 390 × 190	2	20	20	71
None load-bearing fly ash hollow building blocks	240 × 125 × 90	8	80	80	402

Table 3 Terms on the described experiments

Terms	Definitions of terms
Flexural strength	The ability to bend without causing any major deformities
Compressive strength	A measure of a material's ability to withstand compressive pressures, where it is pressed laterally
Frost resistance	The tolerances of extremely low temperature, also known as hardiness or frost resistance
Drying shrinkage	Loss of water held in gel spores that causes volume change. It is a function of the fineness and gel
Carbonization coefficient	The probability model of the coefficient on carbonization speed in the carbonization experiential formula is established on the test data

Products Quality Supervision Center for Building Materials Industry, performance indicators for strength, dry shrinkage and freeze resistance complied with the national standard for building materials industry C239—200l, and the requirements for MUl5 strength grade.

In order to find out more about the product quality, based on fly ash standard brick for example, we selected bricks to test from 100 samples to determine the flexural strength of bricks and obtain a histogram to graphically summarize the display on the distribution of a process data set. Unfortunately some data could not be obtained. The maximum of flexural strength was 4.7 MPa, the minimum was 3.7 MPa and the average was 4.2 MPa. The range of values of flexural strength was 4.2 ± 0.5 MPa. The results showed that the product quality was reliable and only a small deviation, which could meet the quality requirement. The test results are shown in Tables 3 and 4. Various performance targets of the fly ash load-bearing hollow bricks could achieve the industry standard JC239-200l and its strength grade meets the requirements of MUl5. Therefore, it is evident that fly ash can be utilized efficiently.

The strength of fly ash non-load-bearing hollow bricks could reach over 25 MPa, and various performance index for its compressive strength, dry shrinkage, frost resistance and carbonization performance meet the relevant requirements of the national standard GB13545-2002, the industry standard JC862-2000 and intensity level of MU15, respectively. It could be shown from the result that fly ash could be utilized efficiently.

The comparison of the test and existing ones

A comparison between the test and existing ones were conducted. Comparisons were made between technical parameters of equipment in the study to that of existing ones, considering and in relation to the standard brick (please see Table 5). Also it was possible to compare the test results and the results of existing method, as given Tables 6 and 7.

Other test and the results

It is not only a useful attempt of new technology application, but also an important contribution to environmental protection by the application of fly ash in municipal construction [13]. As in the case of kerbstones, the experimental studies validate the use of high fly ash content kerbstones a plant in Anshan City, Liaoning Province, China. In fact, the composition of raw materials for the kerbstones was 52 % of fly ash, 13 % of cement, and the rest were thick and fine gravel, aggregates and additives. The National Highway Engineering Testing Center carried

Table 4 The tested results of high doping coal fly ash brick (steam-cured)

Inspection items		Measuring unit	Criteria of strength Grade MU15	Inspection results	Single evaluation
Flexural strength	Average value	MPa	≥3.3	4.2	Up to standard
	Single piece value min.	MPa	≥2.6	3.7	Up to standard
Compressive strength	Average value	MPa	≥15.0	18.4	Up to standard
	Single piece value min.	MPa	≥11.0	15.9	Up to standard
Frost resistance	Compressive strength	MPa	≥12.0	17.9	Up to standard
	Dry quality loss	%	≤2.0	0.70	Up to standard
Value for drying shrinkage		mm/m	≤0.65	0.51	Up to standard
Carbonization coefficient		/	≥0.8	0.85	Up to standard

Table 5 The tested results of high doping coal fly ash brick (steam-cured)

Inspection items	Measuring unit	Inspection results
Density		
Natural	g/cm^3	1.918
Dry	g/cm^3	1.862
Water absorption	%	10.9
Moisture content	%	3

out the test, and the result showed that the mean value of the strength of the kerbstone was 13.3 MPa, and various performance index for its strength, dry shrinkage and frost resistance met the relevant requirements of the industry standard JTG E41-2005; after-freeze strength test mean was 11.2 MPa with freeze–thaw cyclic events for 50 times; according to projections, strength loss rate was 16.8 %, and the average mass loss rate was 1.5 % about 10 years later.

We proceeded with equipment modification for brick-making production line and carried out brick-making test. In the test, the formula we used was 63 % of fly ash, 10 % of cement, 12 % of sand, 15 % of gravel, 0.05 % of additive, and water-binder ratio was 17 %. Through the process of wheel rolling and mixing, the compressive strength of the product after natural curing for 28 days reached 37.83 MPa.

An abandoned brick production line in a brick plant in Liaoyuan Liaoning Province was renovated and upgraded. The ground paving bricks produced with this line had a fly ash content of 60 %, a cement content of 12 %, a fine stone content of 28 % and an additive content of 0.06 %, and the compressive strength was greater than 40 MPa after curing for 21 days.

Based on the experimental tests and the achievement of the research, we can see that the new technology developed has a very wide practical application prospect in the utilization of fly ash and other industrial waste residues, as

Table 6 The comparison between technical parameters of equipment in the study and existing ones

Making process	Frequency (revolutions per min)	Stress (tons)	Amplitude (mm)	Content of fly ash (%)
Existing technologies	3500–5000	30	≥5	5–30
This research method	6000–8000	60–80	2–4	50–80

Table 7 The comparison between the test results and the results of existing method

Making process of fly ash standard brick	Content of fly ash (%)		Moisture content (%)	Molding compression ratio	Unit weight of wet blank (kg/cm^3)	The condition of surface	Strength grade and freezing-thawing resisting
	Volume ratio	Weight ratio					
Existing technologies	34.8	21.2	19.1	1.83	1815	Smooth surface	Up to standard
	57.7	41.9	21.0	1.81	1788	Small cracks	Below standard
This research method	68.8	57.0	10.9	1.85	1713	Smooth surface	Up to standard
	75.4	61.6	12.0	1.92	1690	Smooth surface	Up to standard
	85.0	68.5	13.3	1.93	1650	Smooth surface	Up to standard
	93.4	75.5	14.8	1.95	1675	Smooth surface	Up to standard

well as in the environmental protection, and cost reducing in relevant enterprises.

Analysis on the test results

The test results showed that the new technology of brick making could consume a large amount of fly ash

For disposal of industrial waste, fly ash could be used as the main raw material in the production of fly ash bricks, its content could be as high as 50–80 %, while water slag and steel slag were auxiliary materials, and the mixed quantity could reach 5–30 %. The main ingredient and the supplementary materials were all industrial wastes and they were available locally. Strength grade and freeze–thaw resistance of the generation of bricklaying building all could reach MUl5 level specified in JC239-2001 national standard for of building materials industry.

Mixed quantity of cement was only 8–13 %, and the cement grade was 425 #, the quantity of fly ash additives in the composition was also small, only 0.03–0.05 %, therefore, the cost of the project's product was obviously lower, and it showed good economic benefit for application.

This test had limitations. The test was strict in certain equipment requirements, and only when the equipment requirements were met, various specifications of load-bearing bricks, non-load-bearing hollow bricks, color ground paving bricks, kerbstones and other products could be produced. When changing the technical parameters and machine mould system, then, the standard bricks, load-bearing bricks, none load-bearing hollow bricks, color ground paving bricks, kerbstones and other products can be produced.

Various performance indexes of the test products could all reach relevant national industry standards. We had manufactured a few products and put into use. The wall construction of the office building for Water Supply Company of Tiexi District Anshan City, the ground paving for a residence community in Tiedong District Anshan City, etc., all used the new technology products with different quantity and different kinds, and information feedback from the users was good. This provided practical support for later batch production and promotion of the project products. It had become true that fly ash bricks will replace red bricks made with clay.

Using waste and developing cycle economy

Fly ash was an industrial waste, it not only occupied farmland, but also polluted environment. Using waste could make the environment around us cleaner and cleaner. It was concluded that the new technology of brick making could consume a large amount of fly ash and industrial wastes. Fly ash could be used as the main raw material in the production of fly ash bricks, with its proportion reaching as high as 50–80, and 5–30 % in cases where water slag and steel slag were used as auxiliary materials. The main and auxiliary materials were all industrial wastes which were available locally. Both strength grade and freeze–thaw resistance of the studied bricks could reach MUl5 level specified in JC239-2001 national standard for industrial building materials.

Reducing costs and increasing economic benefits

Net financial benefit was a question every enterprise needs to consider and study. The research of the project could use waster, reduce costs and enhance very good economic benefit. In the studied process, the mixed quantity of cement was only 8–13 %, and the cement grade was 425 #; the quantity of fly ash additives was also small, with a ratio of only 0.03–0.05 %; therefore, the cost of the project's product was obviously lower, with great economic prospects.

Moreover, the equipment played an important role in accomplishing the project. This test had limitations. The test was strict in certain equipment requirements, and only when the equipment requirements were met, various specifications of load-bearing bricks, none load-bearing hollow bricks, color ground paving bricks, kerbstones and other products could be produced.

Practical application proves the result satisfactory

It was proved by practical application that the established testing mode was reasonable and had good economic and social benefits. Various performance indexes of the test products could all reach relevant national industry standards. We had manufactured a few products and put them into use. Products of different quantities and various kinds had been used in the wall construction of the office building for Water Supply Company of Tiexi District Anshan City, and the ground paving for a residence community in Tiedong District Anshan City. Feedbacks from the users were positive, thus providing practical supports for later production and promotion, making possible the fly ash bricks' replacement of red bricks.

Application prospect and conclusion

The theory that "man is an integral part of nature" in Chinese culture advocates to absorb the natural spirit and interest from mind and esthetics [14].

This project research has a broad application prospect. Firstly, it will change the backward, noisy and rough situation of the design and manufacturing of the present mechanical device for building blocks in China, and make its design and manufacturing to reach the international advanced technology level. Secondly, it will consume mass fly ash to produce blocks, which will reduce the production cost, and the production enterprises will enjoy the relevant state preferential policy and improve the enterprise economic benefit. Thirdly, it will save energy, increase resource utilization rate and reduce waste. According to experts, if one production line be upgraded with the new technology in a brick plant, about 37,000 tons of fly ash blocks will be produced each year, which can reduce the production cost by 15–20 %. There are about 2200 brick plants in the whole country, and about 48–65 million tons of fly ash can be used in 1 year, so the economic and social values are extraordinary. Therefore, it can expand the scope of the comprehensive utilization of fly ash, increase the utilization rate of fly ash, reduce the consumption of cement, save energy and reduce the emission of pollutants such as CO_2, and promote the use of the new machinery technology, which can improve economic benefit of the wall materials enterprises which produce bricks and building blocks, push forward the innovation of building materials and the development of circular economy.

This research and promotion of project have very important social value and profound historical significance. Enterprises should make a comprehensive utilization of fly ash, gangue, tailing, lean material, scrap material, exhaust gas and other industrial wastes generated in production. The research on new technology for construction brick with large content fly ash will finish the history of traditional clay brick and the idea of "Qin dynasty's bricks and Han dynasty's tiles" for building materials, and develop circular economy, turn waste materials into useful things, help to create a low carbon life and realize the sustainable development.

The project research improves present production technology for making bricks, reduces the cement content by using a great quantity of fly ash in products, saves money and raises business economic benefits. The innovation and development of the block-building enterprise technology are in keeping with the national policy about reducing emissions and protecting the environment, which has significant environmental, economical and societal benefits by comprehensively making use of the recycling resources.

To sum up, fly ash is a comprehensive science and technology, marginal science and technology. The sustainable development of this technology depends on the latest progress of other disciplines. If the fly ash can be rationally used, then the environmental problems can be resolved. We can also develop the new products as a variety of new resources. Environment-friendly building materials with low consumption, low power consumption, less pollution, multi-functional characteristics of recycling can be recycled, set of sustainable development, efficient use of resources, environmental protection, clean production, comprehensive benefits in one, and become the building materials the direction of development and trends, meet human needs and the trend of the times.

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