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Experimental Study on Volume for Fly Ash of Building Block

[1]Ling Wang, [2]He Sun, [3]Zhihui Sun and [4]Enqing Ma
[1]University of Science and Technology Liaoning, Anshan, 114051, China
[2]Northeastern University, 110004, China
[3]University of Science and Technology Beijing, Beijing, 100083, China
[4]CEC Environmental Protection Science and Technology Development Liaoning Co., Ltd., 114002, China

Abstract: Fly ash is a waste substance from thermal power plants, steel mills, etc. That is found in abundance in the world. It has polluted the environment, wasting the cultivated land. This study introduces an experimental research on fly ash being reused effectively, the study introduces raw materials of fly ash brick, production process and product inspection, fly ash content could be amounted to 40%~75%. High doping fly ash bricks are manufactured, which selects wet fly ash from the power plants, adding aggregate with reasonable ratio and additives with reasonable dosage and do the experimental research on manufacture products for properties, production technology and selection about technology parameter of production equipment. Index of strength grade and freezing-thawing resisting etc and the high doping fly ash brick building which we are working on can achieve the national standard on building materials industry. Based on the tests, this achievement of research has a very wide practical prospect in using fly ash, industrial waste residue, environmental protection and reducing the cost of enterprises. The efficient reuse of fly ash from coal boiler and power plants has very vital significance of protecting the environment, benefiting descendants and developing of circular economy.

Keywords: Building block, experiment, flies ash, inspection waste

INTRODUCTION

Fly ash is a waste substance from thermal power plants, steel mills, etc. Fly ash is the residue from burning powdered coal, caught by precipitators. That is found in abundance in the world. 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, caused the waste of lots of 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 (Development and Reform Commission Anshan, 2005).

Because of increasing population, human activity has become a dominant process modifying the continents and their environment. Understanding the new environmental stresses, the present scientific effort is inadequate and is not providing the data necessary and appropriate methods for rational decision-making in critical areas, such as global energy production, resource development, recycling economy and environmental protection (Fyfe, 1981).

Coal fly ash from power plants around the world hoards in every corner of the earth, which pollutes the environment and damages cultivated land. The wastes from thermal power plants and steel mills are unwanted, currently uneconomic, solid and liquid materials found at or near its sites. Fly ash is one of the world's largest waste streams and it often contains high concentrations of elements and compounds it can have severe effects on ecosystems and humans. Multidisciplinary research on the fly ash focuses on understanding their character, stability, impact, remediation and reuse. This research must continue if we are to understand and sustainably manage the immense quantities of historic, contemporary and future wastes from thermal power plants, given the trend to manufacture larger deposits of lower-grade raw materials (Hudson-Edwards *et al*., 2011).

In recent years, utilization of fly ash has gained much attention in public and industry, which has helped reduce the environmental burden and enhance economic benefit. In many countries throughout the world, fly and bottom ashes originating from coal-fired thermal power plants are declared as wastes requiring special care during reuse and disposal. In this regard, a number of toxicity tests have been developed to assess the damage of ash residues. For example, by using the batch, continuous and column leaching methods, an attempt has been made to study the behavior of various metal ions release in water from two fly ash samples collected from two thermal power plants in Orissa, India. The experts of the USEPA extraction procedure

Corresponding Author: Ling Wang, University of Science and Technology Liaoning, Anshan, 114051, China

have observed several hazardous elements from both the fly ash samples (Andrew *et al*., 2002).

A major shift to coal as an energy source adjunct with more stringent air quality standards will result in the increasing production of vast quantities of the already difficult-to-dispose coal residues in the United States. Since coal residues contain potentially hazardous substances, improper handling and disposal could cause undesirable environmental effects (Kanungo and Mohapatra, 1998).

Epidemiologic studies have demonstrated increased human morbidity and mortality with elevations in the concentration of ambient air particulate matter (PM). Fugitive fly ash from the combustion of oil and residual fuel oil significantly contributes to the ambient air particle burden. Fly ash is remarkable in the capacity to provoke injury in experimental systems (Adriano *et al*., 2003).

The present study focuses on existing practices related to the reuse of fly ash and identifies new potential uses. All possible applications were identified and grouped into four main categories: construction materials (cement, concrete, ceramics, glass and glass-ceramics); geotechnical applications (road pavement, embankments); "agriculture" (soil amendment); and, miscellaneous (sorbent, sludge conditioning). The results presented here show 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 (Ferreira *et al*., 2003).

For example, finding means of utilizing waste products is a very important field of research at the moment. In this study, fly ash, a waste product of the electricity and petrochemical industries, was investigated as a basic ingredient of a new geological polymer material (Swanepoel and Strydom, 2002).

The research on reuse of Coal ash effectively has very important significance for protecting the environment and developing circular economy. Construction industry that comprehensively utilizes resource, especially fly ash and industrial solid waste is most effective and the largest amount realm. In recent years, an emerging technology known as high-performance high-volume fly ash concrete has become available, which incorporates large volumes of fly ash into conventional portland cement concrete (Malhotra, 2002).

The challenge for the civil engineering community in the near future will be to realize projects in harmony with the concept of sustainable development and this involves the use of high-performance materials produced at reasonable cost with the lowest possible environmental impact. Portland cement concrete is a major construction material worldwide. Unfortunately, the production of portland cement releases large amounts of CO_2 into the atmosphere and because this gas is a major contributor to the greenhouse effect and the global warming of the planet, the developed countries are considering very severe regulations and limitations on the CO_2 emissions. In view of the global sustainable development, it is imperative that supplementary cementing materials be used to replace large proportions of cement in the concrete industry and the most available supplementary cementing material worldwide is fly ash, a by-product of thermal power stations. To considerably increase the utilization of fly ash that is otherwise being wasted and to have a significant impact on the production of cement, it is necessary to advocate the use of concrete that will incorporate large amounts of fly ash as a replacement for cement. Such concrete, however, must demonstrate performance comparable to that of conventional portland cement concrete and must be cost effective (Bilodeau *et al*., 2003).

Presents the results of investigations to determine the various durability aspects of high-volume fly ash concrete using eight fly ashes and two portland cements from U.S. sources. Briefly, in high-volume fly ash concrete, the water and cement content are kept low, at about 115 and 115 kg/m^3 of concrete, respectively and the proportion of fly ash in the total cementitious materials content ranges from 55 to 60 percent (Alain and Malhotra, 2000).

The study makes a case for applicability use in the construction of building blocks in developing countries like China. In china, some wall experts and brick making enterprises have got some achievements in research on how to use the fly ash 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. This study introduces an experimental investigation about fly ash being reused effectively, present a kind of new technology for building brick making, with which fly ash content in brick may reach 40%~75% and practice and theory supports are provided for the development and production of high doping fly ash brick (Wangling *et al*., 2007).

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 circular economy. Field and laboratory tests on fly ash

from power plant disposal areas are presented with parameters for design and construction of fly ash products.

MATERIALS AND TEST METHODS

Brick building using fly ash has got more and more attention. How to make bricks out of industrial waste, how to comprehensively reuse fly ash in large quantities have become the focus. The present study focuses on existing practices related to the reuse of fly ash and identifies new potential uses.

Test sites: A brick plant in Anshan City and a brick plant in Dalian City, Liaoning Province, China.

Raw materials:

- **Coal ash 1:** Fine and wet fly ash from Anshan Power Plant, it was deposited at Mayitun and was Level 3 ash, the chemical composition Table 1,
- **Coal ash 2:** Fine and wet fly ash from Dalian power plant, it was deposited at Mayitun and was Level 3 ash, the chemical composition Table 2,
- **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 produced by CEC Environmental Protection Science and Technology Development Liaoning Co., Ltd.

Ratio of raw materials: Main materials, fly ash, aggregate and additives were prepared in certain weight proportion.

- **Ratio of materials mass for fly ash brick:**

  Fly ash 40% ~ 75%
  Cement 8% ~ 20%
  Aggregate 15% ~ 35%
  Additive 0.03% ~ 0.10%

- **Ratio of materials mass for color fly ash brick:** When products for decoration are produced, the process for stone powder shall be started.
  Fly ash 70%~75%
  Stone powder and gravel for Chromatic adornment (diameter 3-5mm) 10%~15%
  Cement (Grade 42.5) 15%~20%
  Additive 0.05%~0.08%

Test equipment and production process:

- **Main equipments:** H-240 forming machine made in Korea includes hydraulic device, control and operator's desk, chain conveyor and some moulds and the motor power is 36.25 KW, vibration frequency is 6000~7000 times per minute and the press force is greater than 60 T.
  Model of H-240-1 forming machine made in Anshan includes hydraulic device, control and operator's desk, chain conveyor and some moulds, vibration frequency is 7000~8000 times per minute and the press force is greater than 100 T.
  A China made CKS-1500-1 mixer rolling machine with a motor power of 22 KW.
- **Technological requirements:** Firstly, we put together fly ash, cement and aggregate according to mixing ratio and then roll and mix it for three minutes; secondly, add a small amount of water in the fly ash additives, dilute and stir well and put it into the mixture to stir even. For different products, particles degrees used for slag and chemical composition of coal fly ash were different and different technology formula should be used.

  Attention, when the process of production and operation is underway, the mixture of fly ash should be in half dry condition.

Table 1: Chemical composition of coal fly ash 1

Coal Fly Ash 1: fine and wet fly ash from anshan power plant										
Composition	SiO_2	Al_2O_3	Fe_2O_3	CaO	Na_2O	SO_3	K_2O	MgO	Moisture content	Loss on ignition (Σ)
Content (%)	53.7	27.6	6.2	3.2	0.8	0.3	1.76	1.6	0.17	3.3

Table 2: Chemical composition of coal fly ash 2

Coal Fly Ash 2: fine and wet fly ash from dalian power plant									
Composition	SiO_2	Al_2O_3	Fe_2O_3	CaO	Na_2O	SO_3	K_2O	MgO	Loss on ignition (Σ)
Content (%)	48	15.41	34	16.42	1.03	0.18	1.07	5.66	5.89

Table 3: Ratio of raw materials and parameter of machine

	Fly Ash 2	Cement	Aggregate	Fly ash additive	Vibration frequency	Pressure
Test 1	40% ~ 45%	20% ~ 30%	25% ~ 45%	0.03% ~ 0.08%	3500-4000 min-1	60T
	Fly ash1	Cement	Aggregate	Fly ash additive	Vibration frequency	Pressure
Test 2	60% ~ 75%	8% ~ 12%	15% ~ 35%	0.03% ~ 0.08%	6000-7000 min-1	80T
Test 3	80% ~ 90%	5% ~ 10%	10% ~ 15%	0.08% ~ 0.10%	7000-8000 min-1	100T

- **Three experiments:** Ratio of raw materials and parameter of machine as shown in (Table 3).

RESULTS

The manufactured samples and performance indicators: The manufactured samples and performance indices (Table 4).

Test products were maintained under atmospheric pressure steam curing in curing room and the temperature is between 40°C and 80°C for four to five hours. The test products could also be 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 is one of the important features of this technology products.

Indices and inspection of products quality: Results of test 1 are shown in Table 5.

Fly ash standard bricks are 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, ingredients, rolling, stirring, vibration forming and atmospheric steam curing.

The ratio of the raw materials: cement 8% ~ 12%, coal fly ash 60% ~ 75%, aggregate 15% ~ 35%, fly ash additive 0.03% ~ 0.08%. The specifications size of test product is 240×115×53 (mm). Tested by the State Silicate 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 industryJC239-200l and the requirements for MUl5 strength grade, it is high quality product and the test results are shown in Table 6 and 7.

Various performance targets of the fly ash load-bearing hollow bricks can achieve the industry standard JC239-200 l and its strength grade meets the requirements of MUl0.

The strength of fly ash non load-bearing hollow bricks could reach above 25 M Pa 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 MU10 respectively. It can be shown from the result that not only fly ash can be utilized efficiently but also waste residue can be done the same.

Results of test 3: Crack emerged, lowered density of the brick, compressive strength decreased, frost resistance decreased.

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.

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 37.83MPa.

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

Table 4: Chart of the samples

Model number of brick manufacture (Coal ash 1)	Specification	Quantity of one-step molding	Quantity of manufacture	Remark
	240×115×90	8	56	402/m^3
Fly ash standard brick	240×115×53	16	96	684/m^3
Fly ash color adornment brick	240×115×53	16	96	684/m^3
Fly ash color ground brick	300×300×53	6	54	39/m^3
	90×390×190	5	50	150/m^3
The fly ash load-bearing	150×390×190	3	30	90/m^3
hollow bricks	190×390×190	2	20	71/m^3
Fly ash blame bearing hollow bricks	240×125×90	8	56	402/m^3
Model number of brick Manufacture (Coal Fly Ash 2)	Specification	Quantity of one-step molding	Quantity of Manufacture	Remark
Fly ash standard brick	240×115×90	8	56	402/m^3
	240×115×53	16	96	684/m^3

Table 5: Results of test 1

Volume	Compressive strength	Value for drying shrinkage	Dry quality loss	Single evaluation
1360kg/m3	10～30Mpa	0.26～0.3 mm/m	0.18%～0.28%	Up to standard

Table 6: The tested results of high doping Coal Fly Ash brick (steam-cured)

Inspection items		Measuring unit	Standard of strength grade for MU15	Inspection results	Single evaluation
Flexural strength	Average value	MPa	≥3.3	4.2	Up to standard
	Single piece of value	MPa	≥ 2.6	3.7	Up to standard
Compressive strength	Average value	MPa	≥15.0	18.4	Up to standard
	Single piece of value	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 7: 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
Contain water rate		%	3

12%, a fine stone content of 28% and an additive content of 0.06% and the compressive strength was greater than 40MPa after curing for 21days.

The achievement of study has a very wide practical prospect in using fly ash, industrial waste residue and environmental protection (Wangling *et al*., 2007).

There were experimental studies about kerbstone with high content fly ash at a kerbstone plant in Anshan. The composition of raw materials for the kerbstone: 52% fly ash, 13% cement and the rest were thick and fine gravel, aggregate and additives. The National Highway Engineering Testing Center carried out the test and the result shows that the mean value of the strength of the Kerbstone was 13.3 MPa, after-freeze strength mean was 11.2 MPa after freeze-thaw circulation for 50 times, strength loss rate was 16.8% and the average mass loss rate was 1.5%.

CONCLUSION

The research on reuse of Coal fly ash effectively has very important significance for protecting the environment and developing circular economy.

Based on the tests, this achievement of research has a very wide practical prospect in using fly ash, industrial waste residue, environmental protection and reducing the cost of enterprises.

The test results show that the new technology of brick making could consume a large amount of fly ash. For disposal of industrial waste, fly ash can be used as the main raw material in the production of fly ash bricks, its content can be as high as 40%~75%, while water slag and steel slag are auxiliary materials and the mixed quantity can reach 5%~30%. The main ingredient and the auxiliary materials are all industrial wastes and they are available locally.

Mixed quantity of cement was only 8%~l 3% 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 shows good economic benefit for application.

This test has limitations. The test was strict in certain equipment requirements and only if when the equipment conditions requirements are met various specifications of 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 standard. We have manufactured a few products and put into use. 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 has become true that fly ash bricks will replace red bricks made with clay. It can reuse and bring about recycling 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 (Shaobin Hongwei, 2006).

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's 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.

Field and laboratory tests on fly ash from power plant disposal areas are presented with parameters for design and construction of fly ash products.

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