Goumans/Senden/van der Sloot, Editors
Waste Materials in Construction: Putting Theory into Practice

Construction Raw Materials from Coal Fired Powerstations

By-products management and quality control

Authors:
J.W. van den Berg
A. Boorsma
Vliegasunie
PO box 301
3730 AH De Bilt
The Netherlands
phone: +31 30 2209109
fax: +31 30 2204444

Abstract

It is a challenge to use the potentials of the by-products of coal combustion. Because of environmental, economical and technical reasons full utilization has to be stimulated.

In the Netherlands, by-products from coal-fired power stations are fully accepted and utilized for 100% as construction raw materials in the building industry.

Vliegasunie has the task to find and encourage responsible (and economically attractive) uses for the by-products. This is only possible when a great deal of attention is paid to quality control. Quality control is needed in order to be able to provide the market with good predictions of the technical quality of the fly ash to be supplied as construction raw material.

Introduction

Vliegasunie (Dutch Fly Ash Corporation) was founded in 1982 by the Dutch electricity generating companies with the task of marketing all the by-products which are produced when electricity is generated using coal as fuel.

As of January 1995 the activities of Vliegasunie were integrated with those of Gemeenschappelijk Kolenbureau Elektriciteitsproduktiebedrijven ("GKE"), the "sister" company which is responsible for the supply of coal to the Dutch power stations. This allows for a better grip on the actual production process.

In the Netherlands there are 8 coal fuelled electricity production units, divided over 6 locations, which used approximately 9 million tons of coal fuel in 1995.

These locations are:

EPZ	Amercentrale Geertruidenberg	Unit A8	645 Mwe
		Unit A9	600 Mwe
EPZ	Centrale Borssele	Unit BS12	403 Mwe
EPON	Centrale Gelderland Nijmegen	Unit G13	602 Mwe
EZH	Centrale Maasvlakte	Unit MV1	518 Mwe
		Unit MV2	518 Mwe
UNA	Hemwegcentrale Amsterdam	Unit HW8	600 Mwe
Demkolec	Buggenum	Unit MC7	250 Mwe (ICCG)

The total coal fuelled electricity production capacity in operation at this moment is 4,136 MWs. The total installed capacity of the Dutch electricity generating companies was approx. 15,000 MW.

The share of coal as fuel for the generation of electricity is about 45 %

The fuel input is as follows:

- natural gas 47 %
- uranium 8 %
- coal 45 %

GKE buys 8-10 million tons of thermal coal annually, accounting for 5% of the world trade in thermal coal. GKE imports coal from a large number of mines spread over different parts of the world. The geographic origin of the coal used in the Netherlands was:

	1995	1996	
Australia	22	4	%
U.S.A.	27	25	%
South Africa	16	21	%
Columbia	16	27	%
Poland	6	5	%
Indonesia	8	16	%
Others	5	2	%

The composition of the blend of coal which is purchased and blended for the power stations is crucially important to the quantity and quality of the by-products produced by electricity generation. The way in which the coal is supplied and stored also affects the characteristics of the fly ash produced.

Therefore the coal is blended before conveying it to the power plants in order to ensure a constant quality.

The coal combustion by-products from the coal fired power stations per annum are:

Pulverized fuel ash (fly ash)	800.000 - 900.000 ton
Bottom ash	100.000 - 120.000 ton
Fluegas desulphurization gypsum (FGD gypsum).	375.000 - 425.000 ton
Coal gasification slag	40.000 - 50.000 ton
Coal gasification fly ash	5.000 - 10.000 ton

The total amount of the coal combustion by-products from coal-fired power stations is between 1.3 and 1.5 million tons.

Fly ash

Pulverized fuel ash is formed during the process of combustion of pulverised coal in the furnace of the power station's boiler.

The coal is ground to powder-coal in coal mills, before being blown by compressed air into the furnace and burned at temperatures ranging between 1300 and 1600 °C, depending on the type of boiler in question.

Coal contains 10 to 15% non-combustible mineral material. Most of this material melts in the furnace. The majority (approximately 90%) of the non-combustible material is transported into the stack by means of the flue gasses, where it solidifies into fine grained ash particles (fly ash). These ash particles are extracted from the fluegases by electro-static precipitators which have an efficiency of almost 100%.

The fly ash extracted from the precipitators is then transported to silos for dry storage. The fly ash which can't be marketed immediately is moistened and stored in open air depots.

Fly ash is primarily used as construction raw material in the building industry.

The applications in the various market areas in 1996 has been:

Cement industry		58 %
- cement production	22 %	
- clinker production	36 %	
Artificial gravel		18 %
Asphalt filler		10 %
Concrete		10 %
Others		4 %

Cement

One of the applications in the cement industry is as raw material for Portland clinker. Portland clinker is manufactured by cindering a homogeneous mixture of ground lime stone and claylike materials. Fly ash can be used as a substitute for these claylike materials because it has practically the same chemical composition.

An other application of fly ash in cement is as raw material for Portland Fly Ash Cement. The cement industry manufactures class A Portland Fly Ash Cement which has the same characteristic properties as normal class A Portland Cement. This is achieved by using a finer ground, high quality Portland clinker and adding approximately 25% high quality fly ash.

Artificial gravel

Fly-ash is used for the manufacture of artificial gravel (Lytag).

Lytag is manufactured by cindering spherical fly ash pellets. The unburned coal particles in the fly ash are used as fuel in the production process. Lytag is produced by VASIM in Nijmegen.

Lytag can be used as replacement material for conventional mineral aggregate such as gravel or crushed rock.

Asphalt filler

Fly ash is also supplied to the asphalt industry as filler in asphalt mixures for road constructions.

Concrete

Finally there is the market segment concrete. In this segment the fly ash is delivered directly to the users, for application in concrete mixures as partial replacement of cement, or as a filler. For these applications the fly ash is delivered under certification.

Bottom ash

Bottom ash is formed by the slagging of ash particles in the lower parts of the furnace. The amalgamated ash falls through open grids in the furnace floor where it is collected in hoppers. The bottom ash is then moistened and stored in open air depots.

The largest market segment here is the application as light weight sub-base material in road construction and other civil constructions, which accounts for 59% of the bottom ash production.
The remaining 41% goes into the manufacture of concrete blocks.

FGD-Gypsum

Fluegas desulphurisation gypsum is formed during the process of removing sulphur dioxide from the fluegases. The fluegases are led through a scrubber and oxidation tower, where they are brought into contact with a lime or limestone suspension. After an interaction with an excess of air, gypsum is formed.
Up until 1992 most of the FGD-gypsum was used for the manufacture of plaster board. Since the middle of 1993, approximately 25% of our FGD-gypsum has been upgraded to anhydride to be used as an additive to influence the setting time of mixes for self levelling floors. The other 75 % is still used for the manufacture of plaster board.

Coal gasification by-products

Integrated Coal Gasification Combined Cycle is a new technology for the generation of electricity. Gasification of coal is a process in which coal is partially oxidated by air, oxygen, steam or carbon dioxide under controlled conditions to produce a fuel gas. The hot fuel gas is cooled in heat exchangers, with the production of steam, and cleaned before combustion in a gas turbine. The offgases from the turbine are used in a boiler to produce additional steam for a steam turbine. The electrical efficiency can be around 45% with minimal impact on the environment. A demonstration-unit of 250 MW_e has been constructed in Buggenum, the Netherlands, based on the Shell Coal Gasification Process.

The by-products coal gasification slag and fly ash are formed in the gasifier reaction vessel and differ clearly from bottom ash and fly ash from pulverized coal-fired boilers. This is due to the reducing conditions and the higher operating temperatures in the gasifier. The slag which runs from the reactor wall is quenched in a water-bath at the bottom of the reactor and subsequently locked out off the system.
The fly ash is separated with a cyclone. Part of the fly ash is recirculated to the gasifier to obtain higher carbon conversion levels. The composition and properties of the fly ash will depend on the degree of recycling.

There will also be a significant difference with respect to the types of ash produced.
In a pulverized coal-fired boiler about 90% of the ash is fly ash and about 10% bottom ash, whereas in the Buggenum gasifier approximately 80% of the ash will end up in the slag and 20% in the fly ash.
Characteristic for the Buggenum unit will be that the sulphur present in the coal is converted to elemental sulphur instead of gypsum as is normal practice in Dutch pulverized coal-fired units.
This pure form of sulphur is a basic raw material for the chemical industry.

A research programme has been started in order to identify timely industrial applications for coal gasification slag and other coal gasification by-products. A steering committee consisting of representatives of Demkolec, KEMA, Novem and the Vliegasunie supervises the research- and development work in accordance with the Industrial Development Program Coal Gasification (IOKV).

The research programme was initially focused on the characterization of coal gasification slag and fly ash. The suitability of coal gasification slag for civil-technical applications was initially investigated on a small scale by means of specimens in the laboratory. Subsequently larger quantities have been produced industrially on pilot plant scale and during the first year of the demonstration period. The properties of these applications have been investigated by laboratory testing (such as leaching behaviour and pressure strength)
The slag was studied as a replacement for sand in concrete and concrete products, in asphalt concrete and civil engineering applications and as an alternative in foundation and filling work. The fly ash was studied for the use in concrete.

Marketing

For the marketing of all the by-products Vliegasunie has a co-operation agreement with a subsidiary of Cementbouw, Vulstof Combinatie Nederland BV ("VCN"). VCN buys all the by-products, fly ash, bottom ash and FGD-gypsum, which are not already reserved either for delivery to existing customers on the basis of long-term contracts or for processing into artificial gravel in the factory of Vasim.
VCN is also responsible for carrying out the logistics for Vliegasunie's existing long-term contracts.

Quality System

General

The Dutch power stations are fuelled with bituminous coal.

As was mentioned earlier GKE imports coal from different parts of the world and from a large number of mines on behalf of the Dutch power stations. The composition of the blend of coal which is purchased and blended for the power stations is crucially important to the quantity and quality of the by-products produced by electricity generation. The way in which the coal is supplied and stored also affects the characteristics of the fly ash produced.

Vliegasunie's integration with GKE is also expected to yield benefits in the area of quality control. Better insight will be possible into the relationship between the quality of coal and that of the construction materials. This is needed in order to be able to provide the market with good predictions of the technical quality of the fly ash to be supplied as construction raw material.

The diversity in geographical origin of the coal in combination with the variety of boiler types, can lead to a great variation in the composition of the fly ash.

Parameter	Average	St. dev.	
SiO_2	55.5	4.2	%
Al_2O_3	26.3	2.8	%
Fe_2O_3	7.5	2.0	%
CaO	4.3	2.2	%
MgO	1.6	0.5	%
Na_2O	0.6	0.4	%
K_2O	1.7	0.5	%
TiO_2	1.4	0.2	%
P_2O_5	0.5	0.4	%
pH	10.7	1.6	-
L.O.I.	4.5	2.3	%
< 32 mu	73.1	7.2	%
< 45 mu	80.9	6.3	%

Average quality of the fly ash produced in the Netherlands

Each application in the various market areas in the building industry has its own specific quality requirements. These requirements are partially dictated in standard specifications as EN-450, ENV 197 and ENV 206, which are being drafted by the CEN, as part of the European Regulations.

Some of the quality requirements are dictated by the relevant industries themselves.

Information System (ISRA)

Vliegasunie's policy is based on the assumption that the construction raw materials which are delivered to its customers will meet quality criteria agreed upon in advance with the customer. In order to meet these criteria, good co-ordination between quality and logistics is essential. In order to achieve this, an Information System for the Marketing of Coal Residues ("ISRA") was set up which provides access to logistical and quality data, and allows the relationships between quantities and qualities of construction materials to be traced.

This system is an important element in the quality system. Following the introduction of the system in 1994, extensive work was carried out on data communication with the power stations. Every attempt was made to align these systems as closely as possible with the information systems of the power stations, and to take advantage of new developments such as links with the weighbridge computers and the Laboratory Information Management Systems (LIMS).

Quality control

Upon delivery to the Netherlands the coal is analysed. Based on the results of this analysis, and taking into account the unit and the burner in which the coal will be fired, it is possible to predict the composition and the quality of the fly ash that will ultimately be produced.

This gives the great advantage of being able to select the possible applications and thus the potential markets for the fly ash before it has been produced.

The quality control is performed at power stations, which have modern and adequately equipped laboratories at their disposal.

Each day samples are taken for chemical and physical analysis. The test results are forwarded to the Information System (ISRA) where they are compared with the results of the aforementioned prognosis. If necessary the logistics concerning the destination of the fly ash can be adjusted.

Depending on the client's quality requirements, extra samples can be taken and analysed before and during the loading of the fly ash. In this way the client can be given the assurance that the particular delivery of fly ash meets his specific requirements.

Certification

Certification entails guaranteeing the quality that is provided by Vliegasunie, both in terms of the materials supplied and in terms of environmental factors. The procedures which are laid down for this purpose cover the whole area of quality control.

The requirements for the utilisation of fly ash in concrete are dictated in the EN 450. Based on these requirements a procedure for the certification of fly ash has been agreed upon with a certification institute. This procedure consists of a set of guide lines for the assessment of fly ash and incorporates an internal quality monitoring scheme, which is performed under the auspices of the certification institute.

The quality control of the fly ash production is part of the internal quality monitoring scheme.

As part of the quality system attention will be paid to the following elements of quality control:

- Quality control procedures
- Quality manual
- Round robin tests
- Sampling procedures

Concluding remarks

In the Netherlands the by-products of the coal fired powerstations are fully accepted as construction raw materials. An adequate quality system is essential for such a measure of market acceptance.