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COAL COMBUSTION PRODUCTS IN EUROPE – VALUABLE RAW MATERIALS FOR THE CONSTRUCTION INDUSTRY

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European Coal Combustion Products Association e.V.

Coal Combustion Products in Europe – Valuable Raw Materials for the Construction Industry

Coal combustion products (CCPs) are produced when electricity is generated in coal-fired power plants. The production of these CCPs has increased over the years due to legal requirements for flue gas cleaning. The utilisation of CCPs is well established in some European countries, based on long term experience and technical as well as environmental benefits.

Wolfgang vom Berg,
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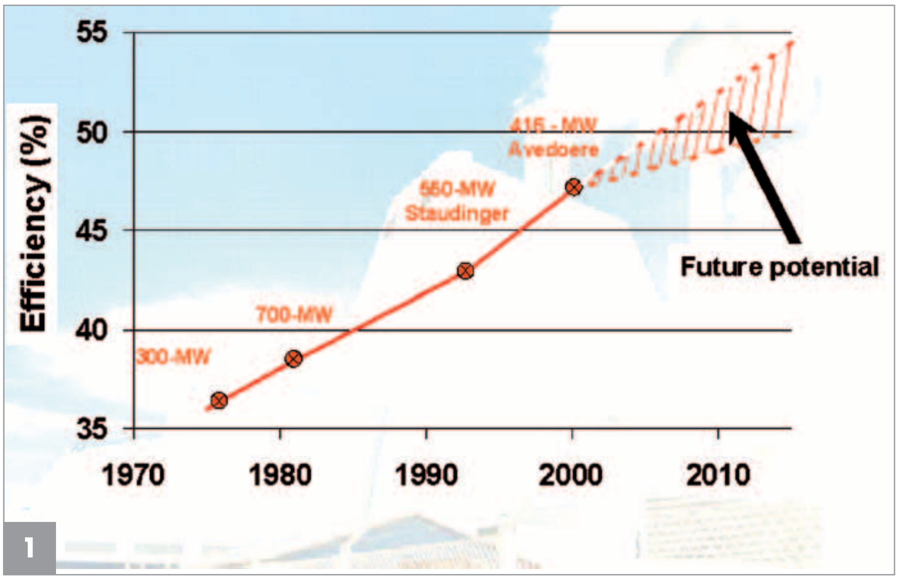
ECOBA

CCPs include combustion residues such as boiler slag, bottom ash and fly ash from different types of boilers as well as desulphurisation products like dry spray absorption products and FGD gypsum. In Europe (EU 15) about 65 million tonnes of CCPs was produced in 2003. The CCPs are mainly utilised in the building material industry, in civil engineering, in road construction, for construction work in underground coal mining as well as for recultivation and restoration purposes in open cast mines. The majority of the CCPs are produced to meet certain requirements of standards or other specifications with respect to utilisation in certain areas. Due to different boundary conditions regarding climate, taxes and legislation the utilisation rate of CCPs differs across Europe. CCPs are defined as waste materials by existing legislation therefore the power industry has to handle the stigma attached to the products and therefore hamper their beneficial use.



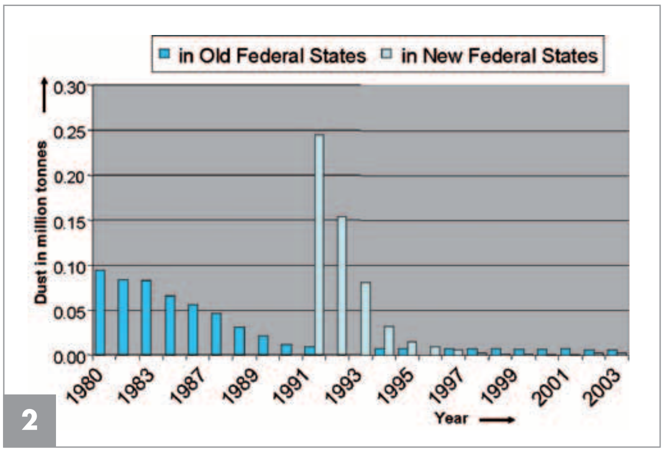
Development in efficiency of coal-fired power plants [Source: VGB PowerTech]

Introduction

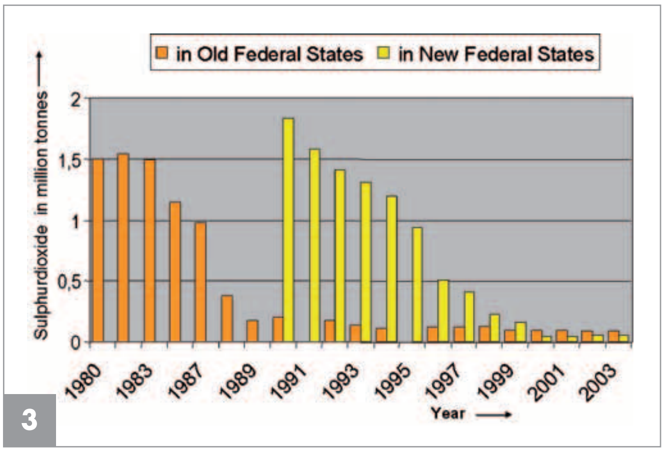
Power and steam production all over the world, including Europe, is based on coal as the most reliable, affordable and safe energy source. All predictions indicate that the total amount of coal used for power production will considerably increase in the future. The use of coal for the generation of power however, has an impact on the environment, which must be kept as low as possible. The coal supply industry as well as the electricity industry are working intensively on establishing Clean Coal Technologies. The development achieved so far is impressive and will continue in the future. The technical improvements are demonstrated by the development in efficiency of power production in condensing power plants during the last 30 years and the prediction for the immediate future shown in **Figure 1**.

Clean coal technology also means low emissions of pollutants to air, water and soil. The example of Germany in **Figures 2 and 3** shows what is possible by flue gas cleaning in this regard. The emissions to the air from coal-fired power plants have been reduced drastically in the past two decades by improving the precipitation of dust from the flue gases and by flue gas desulphurisation. These measures produce an increasing amount of mineral matter along with power and steam (**Figures 4 and 5**).

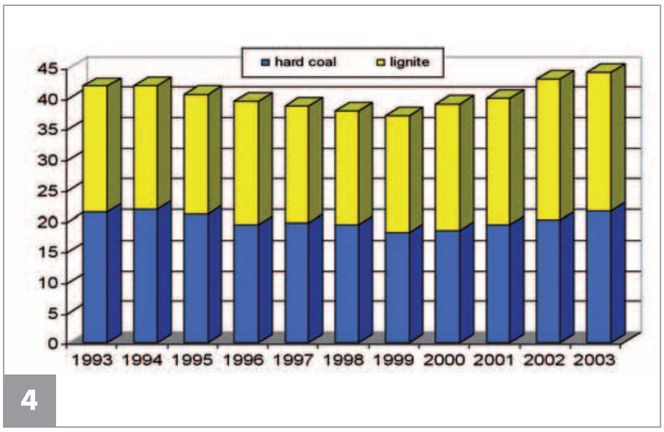
Another important issue of Clean Coal Technology is to avoid the disposal of the minerals produced and to use them as valuable sources. This is where ECOBA becomes involved. In 1990 the European operators of coal-fired power plants along with related marketing companies founded the European Association ECOBA. Its aim is to encourage and promote the necessary legal and regulatory measures for recognition, acceptance and promotion of the use of the minerals produced in coal-fired power plants as valuable recoverable raw and construction materials.



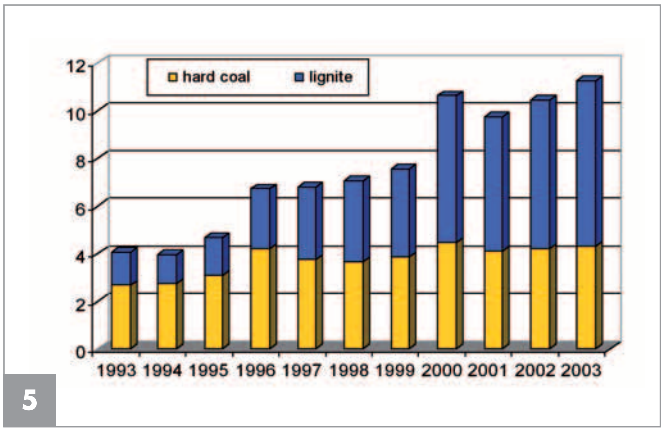
Dust Emissions from German Utility Power Plants [source: VDEW]



SO_2 Emissions from German Utility Power Plants [source: VDEW]



Development of production of fly ash from hard coal and lignite in EU 15 from 1993 to 2003



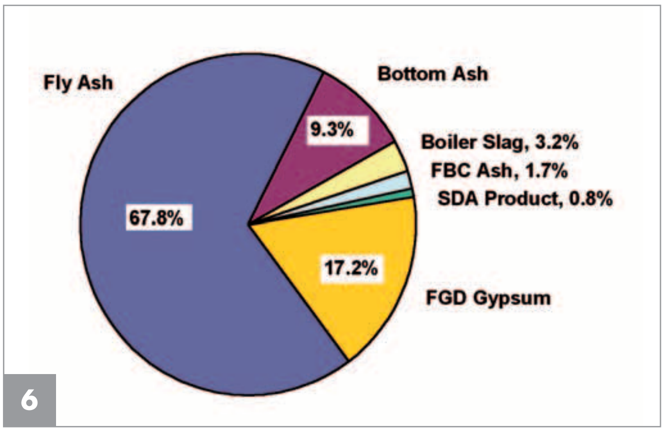
Development of production of FGD gypsum from hard coal and lignite in EU 15 from 1993 to 2003

Production of CCPs in Europe

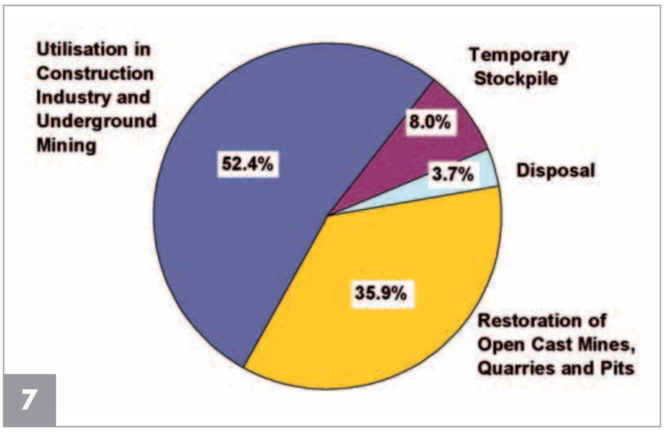
The material under consideration are the ashes i.e. the unburnable mineral matter in the coal and the desulphurisation products obtained from a chemical reaction between the sulphur dioxide, which is derived from the sulphur in the coal during the combustion process, and a calcium based absorbent, in flue gas desulphurisation installations. The total amount of CCPs produced world wide is estimated to be about 550 million tonnes. In the European Union of the EU 15 the production was about 65 million tonnes in 2003 and in the larger EU of 25 member states the total production is estimated to be about 95 million tonnes. Exact figures from the new member states are not yet available. The ECOBA statistics on production and utilisation of CCPs reflect the typical combustion products fly ash (FA), bottom ash (BA), boiler slag (BS) and fluidized bed combustion (FBC) ashes as well as the products from dry or wet flue gas desulphurisation, especially spray dry absorption (SDA) product and flue gas desulphurisation (FGD) gypsum. The amount of CCPs produced in European (EU 15) power plants totalled 65 million tonnes in 2003 [1]. **Figure 6** shows the proportions of the different CCPs produced. Almost 68 wt.-% of the total CCPs is produced as fly ash. All combustion residues account for 81.9 wt.-% and the FGD residues for 18.1 wt.-%.

Dr. Wolfgang vom Berg studied Civil Engineering at Aachen University, Gemany. He was involved in research on the use of fly ash in cement and concrete from its beginning in Germany. In the 1980ies he worked as a consultant in concrete technology with special respect to the use of fly ash as a concrete addition. In 1989 he became head of the department „Utilization/Waste Management" at VGB Technical Association of Large Power Operators (now called VGB PowerTech, a European Association of large power plant operators). Since the foundation of ECOBA European Coal Combustion Products Association in 1990 he has been serving as Secretary General of the association. On behalf of VGB and ECOBA he is member of several national and European standardization committees dealing with the use of CCPs.

Hans-Joachim Feuerborn (1964) studied Metallurgy and Material Science at Aachen Technical University. In 1986 he started his scientific work at the University Technical University Aachen on reuse of industrial residues in construction products. From 1990 he worked as chief engineer in the department of binder materials and as assessor in ceramics and binder materials and as a consultant for reuse of industrial residues. In 2000 he started his work as adviser for by- products from coal-fired power stations at VGB PowerTech, the European technical association for power and heat generation. Furthermore, he is working as Technical Officer for ECOBA, European Coal Combustion Products Association.



Production of CCPs in Europe (EU 15) in 2003 (total production 65 million tonnes)



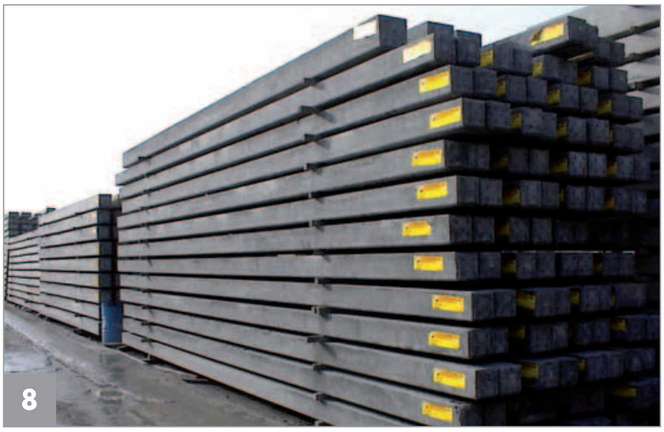
Utilisation and disposal of CCPs in Europe (EU 15) in 2003

Utilisation of CCPs in Europe

Most of the CCPs produced are used in the construction industry, in civil engineering and as construction materials in underground mining (52.4 wt.-%) or for restoration of open cast mines, quarries and pits (35.9 wt.-%). In 2003, about 8.0 wt.-% were temporarily stockpiled for future utilisation and 3.7 wt.-% was disposed of (**Figure 7**).

Utilisation of Fly Ash

Fly ash obtained by electrostatic or mechanical precipitation of dust like particles from the flue gas represents the greatest proportion of the total CCP

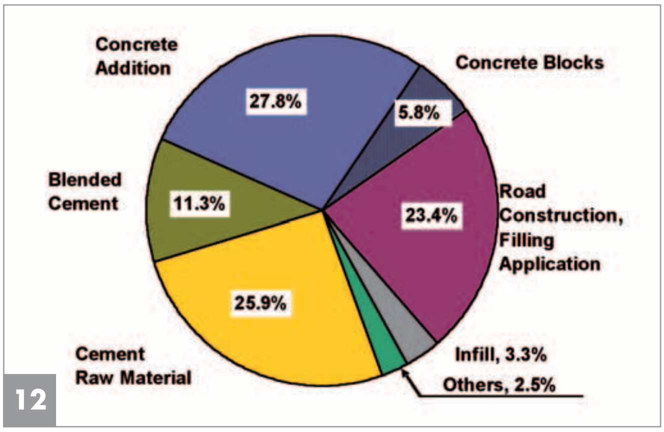


Foundation piles produced with fly ash concrete (source: Lodewikus Vorgespannen Beton/The Netherlands)

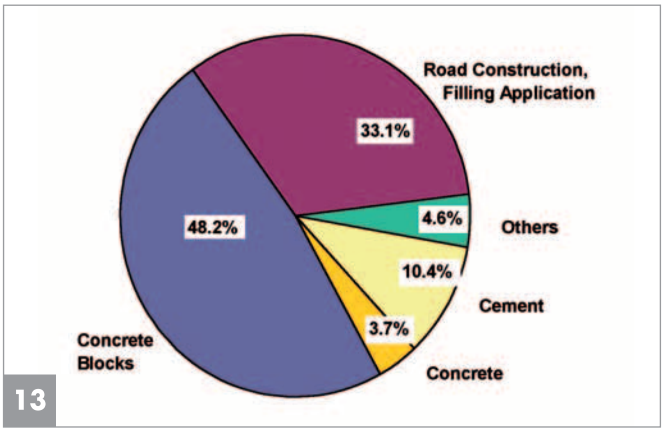
Concrete blocks with fly ash concrete (source: Artebel/Portugal)

Jacking pipe made from acid resistant reinforced concrete (XA2) with fly ash and silika fume (source: BERDING Beton/Germany)

Precast reinforced concrete tank system for waste water treatment with fly ash concrete (XA2), (source: Benno Drössler GmbH & Co.KG/Germany)



Utilisation of fly ash in the construction industry and in underground mining in Europe (EU 15) in 2003 (total utilisation 21.1 million tonnes)



Utilisation of bottom ash in the construction industry and in underground mining in Europe (EU 15) in 2003 (total utilisation 2.7 million tonnes)

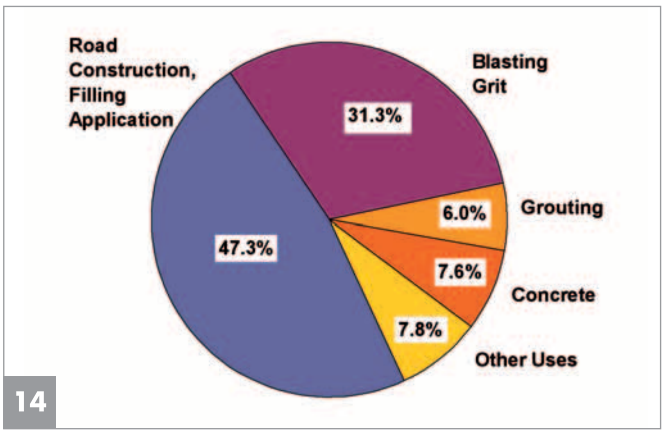
production. Siliceous, silico-calcareous or calcareous fly ashes, depending on the type of coal and the type of boiler, with pozzolanic and/or latent hydraulic properties are produced throughout Europe. The utilisation of fly ash across European countries is different and is mainly based on national experience and tradition.

In 2003, about 21 million tonnes of fly ash was utilised in the construction industry and in underground mining. Most of the fly ash produced in 2003 was used as a concrete addition (**Figures 8- 11**) in road construction and as a raw material for cement clinker production. Fly ash was also utilised in blended cements, in concrete blocks and for infill (that means filling of voids, mine shafts and subsurface mine workings) (**Figure 12**).

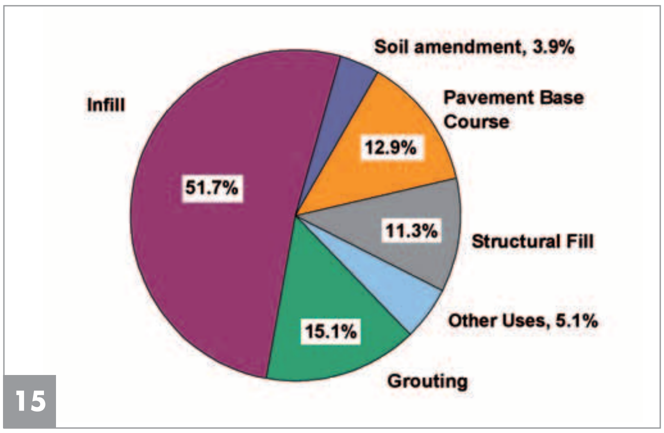
Fly ash is the most important CCP and accounts for nearly 70 wt.-% of the total amount. Approximately 33 wt.-% of the total fly ash produced in Europe is used as a cement raw material, as a constituent in blended cements and as addition for the production of concrete. This means that it is a main constituent of the cement or else it replaces part of the cement necessary for the production of concrete. The use as a concrete addition constitutes the highest added value for fly ash so the European Standard EN 450 "Fly Ash for Concrete" [2] is particularly important for the marketing of fly ash. The standard was first published in 1994 and the revised standards EN 450-1 und EN 450-2 [3, 4] have been published last year by most of the National Standardization Bodies in Europe. The standard only refers to siliceous fly ash. Calcareous fly ash, which is mainly obtained from combustion of lignite, cannot be utilised as a concrete addition according to EN 450.

Utilisation of Bottom Ash

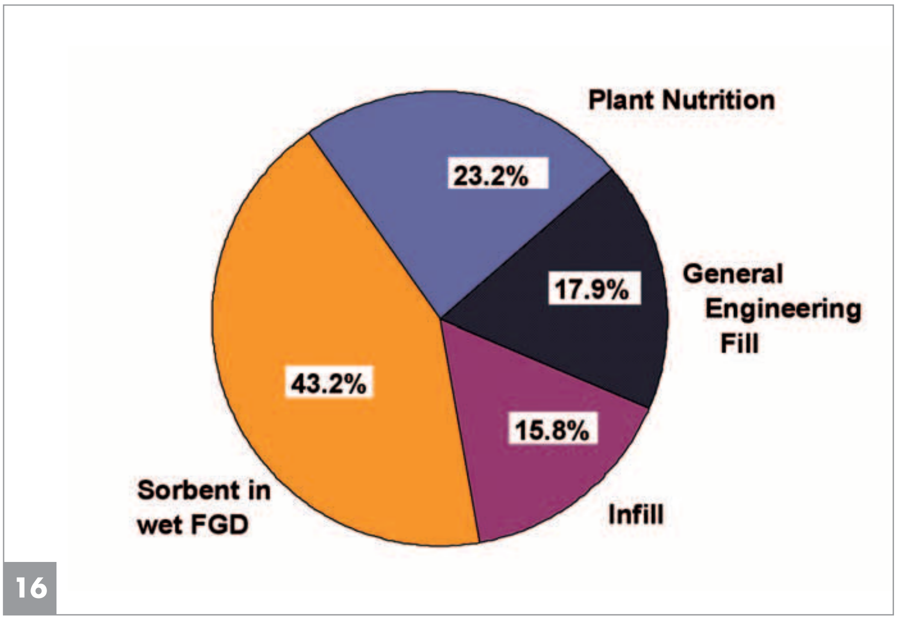
Bottom ash is produced as a granular material and removed from the bottom of dry boilers. It is much coarser than fly ash but is also formed during the combustion of coal. In 2003 about 6 million tonnes of bottom ash was produced in Europe. About 2.7 million tonnes of bottom ash was used in the construction industry. 48 wt.-% of this was used as fine aggregate in concrete blocks, 33 wt.-% in road construction and about 14 wt.-% in cement and concrete (**Figure 13**).



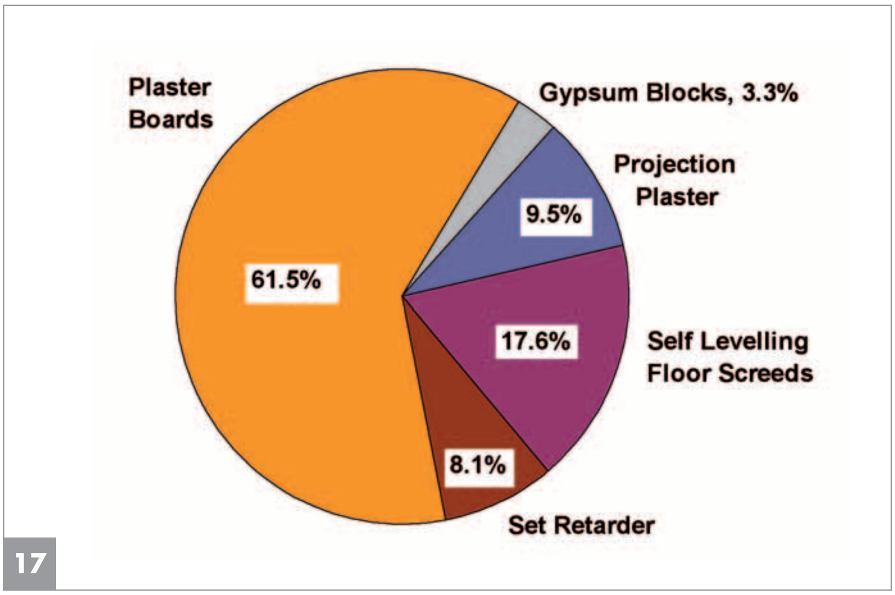
Utilisation of boiler slag in the construction industry and as blasting grit in Europe (EU 15) in 2003 (total utilisation 2.1 million tonnes)



Utilisation of FBC ash in the construction industry and in underground mining in Europe (EU 15) in 2003 (total utilisation 0.5 million tonnes)



Utilisation of SDA product in the construction industry, in underground mining, for plant nutrition and as sorbent in wet FGD in Europe (EU 15) in 2003 (total utilisation 0.1 million tonnes)



Utilisation of FGD gypsum in the construction industry in Europe (EU 15) in 2003 (total utilisation 8.0 million tonnes)

Utilisation of Boiler Slag

Boiler slag is a vitreous granular material derived from coal combustion in wet bottom boilers at temperatures of between 1500 and 1700 °C. Due to high temperatures in the furnace some of the minerals in the boiler melt and flow down into a water bath at the bottom of the boiler where they are cooled down rapidly and form a coarse granular material with a maximum particle diameter of about 8 millimetres. Boiler slag is a glassy, environmentally sound, material of which about 55 wt.-% is used in road construction, e.g. as a drainage layer. Another 26 wt.-% is used as blasting grit and smaller amounts as aggregates in concrete and grouts (**Figure 14**). In 2003, about 2.1 million tonnes of boiler slag was produced in Europe (EU 15). The utilisation rate was 100 wt.-%.

Utilisation of FBC Ash

Fluidized bed combustion (FBC) ash is produced in fluidized bed combustion boilers. The technique combines coal combustion and flue gas desulphurisation in the boiler at combustion temperatures of between 800 and 900 °C. This makes FBC ash rich in lime and sulphate.

The amount of FBC ashes produced in Europe (EU 15) was about 1 million tonnes in 2003. Out of this 0.5 million tonnes were utilised in the construction industry and for mining purposes. About 52 wt.-% of the total FBC ash was used for infilling purposes, i.e. for filling of enclosed voids, mine shafts and subsurface mine workings. About 13 wt.-% was used with the production of pavement base course as foundation materials or as a drying agent for wet soils and about 11 wt.-% was used for structural fill (**Figure 15**). In 2002, about 29 wt.-% of the FBC ash produced had to be disposed of.

Utilisation of SDA Product

About 0.5 million tonnes of spray dry absorption product (SDA product) were produced in 2003 in European power plants using spray dry absorption techniques for desulphurisation of the flue gases. The SDA product is a mixture of the following minerals: calcium sulphite hemihydrate, calcium sulphate di-hydrate (gypsum), calcium carbonate, calcium hydroxide, calcium chloride and calcium fluoride. Depending on the location of the SDA installation in the flue gas stream (upstream or downstream of the electrostatic precipitator) the SDA product may contain up to 60 wt.-% of fly ash. Due to the high content of sulphur and chlorine the SDA product cannot be used in cement-bonded systems used for construction purposes because of the risk of unsoundness. The SDA product is utilised in the mining industry as a component of mining mortar for stabilising underground cavities. In the building material industry it can also be used as an addition in the production of sand lime bricks. About 5 % of the total is used for plant nutrition. It has been proven that SDA product can be used without any harm to the environment as a sulphur fertiliser in agriculture. SDA product is increasingly used as sorbent in the wet FGD process in power plants.

In 2003 nearly 20 wt.-% of the total SDA product was utilised in the construction industry and in underground mining, for plant nutrition and as a sorbent in wet FGD (**Figure 16**), 37 wt.-% was used for restoration purposes and about 44 wt.-% had to be disposed of in disposal sites.

Utilisation of FGD Gypsum

FGD gypsum is produced in the flue gas desulphurisation process of coal-fired power plants incorporating the desulphurisation of the flue gas in the power plant and a refining process in the FGD plant that includes an oxidation process followed by gypsum separation, washing and dewatering. Studies have shown that FGD gypsum has the same properties as gypsum from natural resources regarding health aspects [5]. Based on these results and because of its consistent quality, FGD gypsum is accepted in the gypsum and cement industry as a direct replacement of gypsum from natural sources. FGD gypsum has to meet the quality specifications of the gypsum industry as published by EUROGYPSUM [6].

The amount of FGD gypsum produced in Europe (EU 15) was approximately 11.3 million tonnes in 2003. About two thirds of this material was produced in Germany. Nearly 70 wt.-% of the total FGD gypsum produced in Europe is utilised in the gypsum and cement industry.
In total 14 wt.-% of the FGD gypsum produced was temporarily stockpiled as a raw material base for future utilisation, mostly for plasterboard production, and only 0.7 wt.-% was used in landfill. FGD gypsum is used as a raw material for a number of gypsum products by the gypsum industry because of its purity and homogeneity when compared to natural gypsum. 4.9 million tonnes of FGD gypsum were used in 2003 for the production of plaster boards. Other applications include the production of gypsum blocks, projection plasters and self levelling floor screeds (**Figure 17**). FGD gypsum is used in the cement industry as a set retarder. The total amount of FGD gypsum for this application was about 0.8 million tonnes. To control the set retardation FGD gypsum is often mixed with anhydrite from natural sources in order to take advantage of the different solubility of both minerals.

Environmental benefits of CCP utilisation

In many of the applications developed through the last four decades the utilisation was made possible because of economic advantages. In addition, the utilisation in most applications includes environmental benefits. These benefits are:

- Saving of natural resources
- Saving of energy
- Saving of emissions of pollutants to the air
- Saving of CO_2 emissions
- Saving of disposal space

At least one, and in most cases several, of the benefits apply to all applications of fly ash. The most impressive example is the replacement of a part of cement by fly ash in concrete or the use of fly ash as a main constituent of blended cement. For the production of one tonne of cement about 1.6 tonnes of raw material have to be mined, crushed, calcined and heated to a temperature of between 1200 and 1400 °C. In addition, 0.95 tonnes of material have to be finely ground to produce Portland cement. 2900 MJ of thermal energy and 100 kWh of electrical energy are needed for the production of one tonne of Portland cement [7]. The production of Portland cement is not possible without emissions of pollutants to the atmosphere even though the emissions from cement production have been drastically reduced in the last few decades. The production of Portland cement is also inevitably associated with CO_2 emissions due to the calcination process and the energy demand. The replacement of Portland cement by fly ash therefore reduces the various environmental impacts associated with cement production. Many of the other uses of CCPs do at the very least avoid the environmental impacts of the mining of natural resources and the processing of the minerals and save the space needed for the disposal of CCPs.

Environmental compatibility of the use of CCPs

The many environmental benefits connected with the use of CCPs are listed above, but nevertheless the environmental impact of the use of CCPs has to be considered in any application. Fly ash and bottom ash, like any natural minerals, contain a certain amount of trace element compounds. The concentrations of some of these trace elements may be higher in fly ash than in natural minerals or products used for a certain application. Regulations have been developed for the different uses of industrial by-products at a national level in the European member states in order to avoid any negative impact on the environment or even on human health.

Standardisation of these regulations are currently taking place at a European level in order to harmonise the procedures and regulations currently existing in the member states. As a result of the environmental regulations there have so far not been any reports of negative impact on the environment or on human health caused by the utilisation of CCPs.

Legal status of CCPs

The utilisation of CCPs is practised today, and has been practised in the past, in a technically and environmentally sound manner and provides considerable environmental benefits. For this reason, the utilisation of CCPs not only contributes to the Clean Coal Technology but also supports sustainability in the construction and building industry. The fly ash industry therefore asks the relevant authorities, and in particular the European Commission, to take these facts into account in their legislative work and to eliminate hurdles and restrictions that are unnecessarily impeding the marketing and the utilisation of CCPs. One of these hurdles is related to the legal status of the CCPs.

Due to the EC Waste Framework Directive, CCPs have legally to be considered as waste. Since the early 90´s discussions have taken place as to whether in certain cases a by-product from industrial processes is covered by the definition, i.e. has to be considered as waste, or whether waste properties could cease at a specific stage of the managing process. A typical example is FGD gypsum, which is on one hand a residue of a pollution abatement process and on the other hand was produced from scrubber sludge by an oxidation, cleaning and drying procedure aiming at a material, which meets technical specifications of the users (gypsum and cement industry). After several years of discussion it is now generally accepted by the authorities that FGD gypsum has ceased the waste properties after processing in the power plant.

The case is not clear for fly ash as it is argued that no processing takes place in the power plant and that the recovery operation is the final use of the material. That would mean that the material is to be handled (collected, transported, stored) as a waste. This means, a concrete producer would use a waste to produce concrete, i.e. a ready mixed concrete plant becomes a waste handling plant. Even if the restrictions or the additional paper work required by the authorities are not too heavy there is the image problem of the concrete, which might become an additional obstacle for the concrete producer to use fly ash.
In the course of a "Communication on Thematic Strategies on the Prevention and Recycling of Waste" launched by the European Commission about two years ago, a new discussion on the legal definition of waste/non-waste/by-product and on disposal/recovery has been initiated. Based on judgements of the European Court of Justice it could be possible that the definitions will be amended. If a by-product of an industrial process is processed or treated for use as a secondary raw material, if it meets certain specifications in given standards and if it is destined for utilisation by a marketing contract this material could be considered as being a non waste. As the European Commission is aiming at increasing recycling and use of secondary raw materials for environmental reasons there is a chance that for these materials the definition would be clarified.

Summary

About 65 million tonnes of Coal Combustion Products (CCPs) were produced in Europe (EU 15) in 2003. The annual production in EU 25 is estimated to amount to about 95 million tonnes. The CCPs include combustion residues such as boiler slag, bottom ash and fly ash from different types of boilers as well as desulphurisation products like spray dry absorption product and FGD gypsum. CCPs are mainly utilised in the building material industry, in civil engineering, in road construction, for construction work in underground coal mining as well as for recultivation and restoration purposes in open cast mining. They are used as a replacement for natural resources. Their utilisation helps to save natural resources and to reduce energy demand and greenhouse gas emissions to the atmosphere caused by mining and generation of products that are replaced by CCPs. The utilisation rate of CCPs was 88.3 % in the EU 15 in 2003, including the use in restoration and reclamation of open cast mines. Another 8 % has been stockpiled in temporarily stockpiles for future utilisation.

The utilisation is becoming more and more restricted by environmental regulations. In addition, the legal definition of CCPs as waste causes hurdles, which are unnecessarily impeding the utilisation market. The electricity industry and the CCP industry urge authorities to take facts into account in their legislative work. In order to secure the established utilisation markets the CCP industry needs a clear definition of when waste ceases to be waste during the utilisation process.

References

[1] ECOBA: Statistics on Production and Utilisation of CCPs in Europe (EU 15) in 2003
[2] European Standard EN 450, Fly Ash for Concrete, September 1994
[3] EN 450-1: Fly ash for concrete – Part 1: Definitions, specifications and conformity criteria, 2005
[4] EN 450-2: Fly ash for concrete – Part 2: Conformity evaluation, 2005
[5] Beckert, J., Einbrodt, H.-J., Fischer, M.: Comparison of Natural Gypsum and FGD Gypsum, Abridged Version of the VGB Research-Project 88, VGB Kraftwerkstechnik 1991, p. 46 - 49
[6] EUROGYPSUM: FGD Gypsum - Quality Criteria and Analysis Methods, Association of European Gypsum Industries, Brussels
[7] Verein Deutscher Zementwerke e.V. (VDZ): Umweltdaten der deutschen Zementindustrie (Environmental data of the German cement industry), September 2000

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