Current State and Prospects of Increased Product-Oriented Utilization of CCPs

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Summary

At present, the situation in utilisation of combustion products in Poland should be viewed as a positive outcome of efforts of research and implementation centres associated with the power sector, as well as of users on the market. This was in large extent facilitated by emerging new companies concentrating not solely on transport tasks but also on active development of new ways of utilisation.
As using pure coal fuel for power generation gives place to optimisation by co-combustion of other fuels with coal, which impacts the properties of arising fly ashes, slags and flue-gas desulphurisation products, it is necessary to further study the physico-chemical properties and toxicity behaviours of these new products and make public the results of both research and practical application.
It seems appropriate to consider the production of varieties of processed ash, such as quality, activated and hydrophobic ash, in order to increase the overall scope of utilization. In terms of high-quality products it seems desirable to develop manufacturing of cenospheres in dry technologies as well as metal-concentrates, micro- and nano-fillers, and carriers. Successful utilization of deposited ashes should bring about large economic effects, also in terms of recovery of land suitable for development.

Keywords: coal combustion products, fly ash, slag, flue-gas desulphurization products, utilization of solid residues of coal combustion, quality ash

Introduction

With development of new production technologies of various goods and energy as well as implementation of human environment protection principles, we are creators of the growing use of combustion products as valuable raw materials and mineral products. Currently, their source are combustion products arising from exploited power facilities incinerating any kind of solid fuel derived from bare grounds containing combustion products. In a number countries where coal combustion limitation occurred, there is increasing importance of coal combustion products accumulated in all classes of landfills as a sources of soil masses, aggregates, binders, etc.

Last 20 years is an example of the rational use of coal combustion products and development of new management directions. In the department of mass and rational management of combustion products one should underline a large contribution of Polish scientists, engineers, economists and industrial managers. Present situation was and is influenced by new system of combustion products management that is based on formation of a number of organizations of transport as well as development of management directions. Summary of achievements and problems not only in Poland but also in countries belonging to the ECOBA (European Coal Combustion Products Association, Essen) was presented by Polish Union of Combustion Products on Jubilee International Conference "Ashes from Energetics" [1].

Development of the use of coal combustion products are often accompanied by disseminated opinions, repeatedly inappropriate (pneumoconiosis, radioactivity, hazardous waste), periodically causing an unfriendly atmosphere and disruptions in their management. Currently, we all are facing solution of the problem of ammonia and mercury contents in fly ash.

Analysis of the current development directions of combustion products indicates, that some of them do not cover the problem and can be a source of increase of their rational use and ecological and economic effects. Simultaneously, we observe abroad the development of new application and research in the field of innovative extension of their use.

Among many directions of enhancing the rational development of combustion products we may distinguish research and implementation in the field:

- Enhance of recovery of cenospheres from fly ashes from current production and landfills;
- Increase the production and application of activated ashes;
- Initiation the production and application of fractional fly ash (quality ash);
- Production of hydrophobized fly ash;
- Recovery of metal concentrates;
- Extension and systematic works on managing by-products from combustion of non-carbon fuels and their composition with coal;
- Recognition of purpose and possibilities of manufacturing nano-products from fly ashes as active components of binders and cements as well as fillers for plastics and rubber and catalyst supports, plant

protection etc.

Physical and chemical properties of fly ashes

Knowledge of the composition and properties of physical, chemical and mineralogical characteristics of fly ashes and slags allows for their multidirectional management. A number of these possibilities, generally known by now, are fulfilled with not always available materials [2,3].

As long as "natural" fly ash comforts a number of requirements and is used for production of cement and binders, concrete and ceramics, and is used as hydro-, thermo- and gaseous isolating, the extraction of specific grain fractions enhances the individual characteristics of the ashes simultaneously creating new opportunities and areas of application of fly ashes.

Research on changes in physical and chemical properties of fly ash along with increase of the contribution of the finest fractions delivers following observations:

- Increase of the specific surface area;
- Increase of pozzolanic properties;
- Increase of light metal compounds content;
- Improvement of properties of rheological water suspensions, concrete mixtures etc.;
- Decrease of gaseous and liquid medium filtration;
- Periodical (within a certain range of graining);
- Periodical increase of cenospheres content;
- Periodical increase of content of components having magnetite properties.

A rough extraction of grain fractions is sometimes accomplished by collecting ashes from individual electrofilters' hoppers. Secretion of specified grain fractions in the range up to 30 μm is usually performed on a mechanical vibrating sieve. Mass fraction secretion, practically of any composition, is the most frequently done in the pneumatic separators (air).

Changes in physicochemical properties of fly ashes and extraction of specific groups of compounds can be performed by their appropriate treatment, namely:

- Additional grinding, causes not only specific surface area increase, but also increase of hydraulic activity and decrease of permeability factors, including water permeability;
- Agglomeration, granulation and briquetting of fly ashes and flue gas desulfurisation products allows to obtain new materials of aggregates properties, material dust-free and resistant to the effects of certain conditions for their use or disposal, including weather conditions;
- Hydrophobising, changes the surface character of ash grains from hydrophilic or weakly hydrophobic into hydrophobic by coating their surface with mineral and synthetic oils as well as with organic compounds (amines, silicones). As a result, the water permeability of ash bed is obtained; decrease of surface tensions between ash-oil/ash-organic compounds, which increases their use for de-oiling of water and sewage as fillers for plastics and rubber, and in addition, as a plant protection products;
- Magnetic treatment, causes separation of the non-magnetic grains from magnetic grains; resulting product is fly ash having lower specific density and iron oxide concentrate, which are both used for preparation of heavy liquid in mining as well as drilling fluid and as a component of concrete shielding against radioactive sources;
- Electrostatic treatment, uses differences in electrifying of the individual components in the electric field, thereby quick coke grains are effectively extracted from fly ashes;
- Thermal treatment, depending on the temperature, one can conduct drying processes of wet ash mixtures and their products, gypsum dehydration, combustion of quick cokes contained in fly ashes and slags and processes of desublimation of light metal oxides, but one can mostly carry out sintering processes (light aggregates) and fusing (slag wool, high abrasion resist casting) of fly ashes and slags;
- Enrichment via flotation, involves differences of wettability of components of fly ashes and becomes useful for removing the quick coke grains with simultaneous cenosphere secretion;
- Chemical treatment of ash grain surfaces that leads to removal of absorbed components (ammonium compounds, mercury etc.) and to creation of zeolites and light metals concentrates (germanium, gallium). These methods are also used for the chemical extraction of aluminum compounds, titanium and other elements from the aluminasilicates structures that occur in fly ashes.

Along with coal combustion technique development and processing technology and use of the ashes, it is indispensable to explore the composition and properties of CCPs and appropriate response to emerging issues. A good and effective way to solve these types of problems are European research in the frames of REACH [4]. Currently, the most discussed problems are related to presence of ammonia and mercury compounds in fly ashes.

The presence of ammonia in the fly ashes is characteristic of processes of reduction nitrogen oxides (NOx) with ammonia and urea in the exhaust gas. Depending on the technology used for NOx reduction and ammonia dosing accuracy, fly ashes contain varying contents of ammonia. In the 80s, high-rise building in the USA demonstrated ammonia excretion from concrete, that seriously threatened the working conditions. To reconcile the need of reduction of NOx and safe use of ashes, the standardization limit of ammonia content have been implemented. In the USA ashes containing more than 100 mg per 1 kg are not allowed to be used in concrete. However, such situation have led to decreased access to useful fly ashes in concrete.

With currently available technologies for removal of ammonia from fly ashes, special attention is drawn by method developed by and American company – Separation Technologies – which, in 2008, run three installations that remove ammonia from ashes [5]. This method consists in intensive stirring of fly ash to which less than 2 % of burnt lime and from 1 to 3 % of water is added, suction of release ammonia, while ash is dried and becomes useful component for concretes. The essence of the method is formation of calcium hydroxide, which as a stronger base, displaces ammonia from grain surface of the ash. Ammonia is used for neutralization of the nitrogen oxides in catalytic method of neutralization of flue gases from ash dryer. The technology allows for reduction of the ammonia content of less than 50 mg/kg of fly ashes containing from 200 to 3000 mg/kg.

Partial reduction of the ammonia content in the ash can also be obtained by washing the grains of ash with air. Higher ammonia content reduction can be obtained by means of air washing and/or suction at elevated temperatures. Relatively simplest solution would be air washing of warm ashes discharged from installation hoppers (e.g. in aeration gutter with intensive venting) or treatment in vacuum conditions.

Available publications on the content of mercury and its compounds in the coal and combustion products show a large variation of its occurrence, depending on the burned coal. Polish coals contain from 13 to 399 ppb of mercury, with the average of 85 to 100 ppb [6, 7, 8].

Hard coals used in power industry contain from 53 to 141 ppb, while lignites from 117 to 370 ppb [8]. In contrast, fly ashes and slags obtained from hard coals contained 126 to 1000 ppb and 2 to 30 ppb, respectively; fly ashes and slags from lignites contained 125 to 1377 and 14 to 370 ppb, respectively.

Generalized results of flue gases showed, that about 33 % of mercury and its compounds is precipitated in the electrofilter and about 36 % in the system

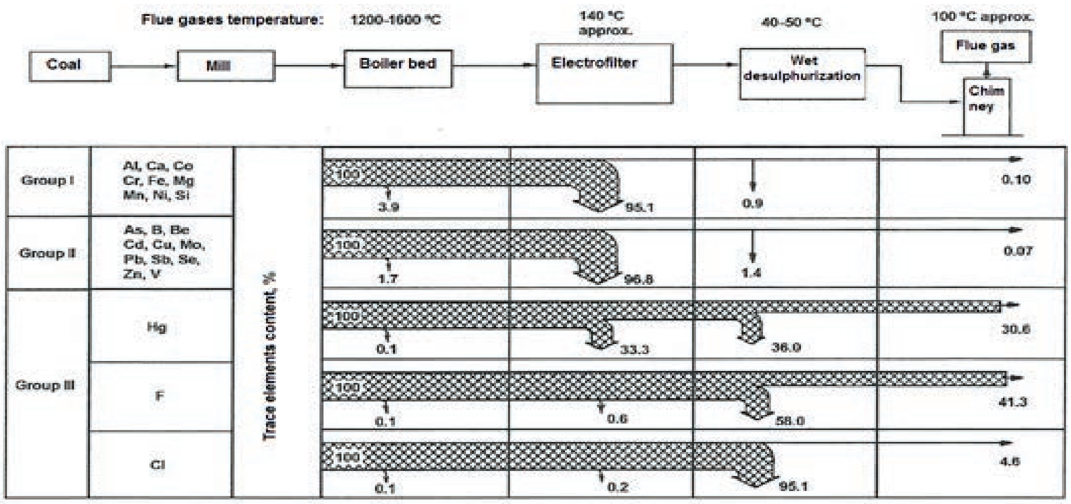

Fig.1. Mass balance of heavy metals, fluorides and chlorides in CCPs [9].

Rys. 1. Bilans masowy ciężkich metali, fluorków i chlorków w produktach spalania węgla[9]

of wet desulphurization, the remaining amount of 37 % is carried away with the flue gas – Fig.1. [9].

The absolute amount of mercury in the ashes precipitated in electrofilters and fabric filters depends on the mercury and ash contents in burned coal. Concentration of mercury in fly ashes always decreases with increase of ash concentration in coal. In addition, a decrease of mercury concentration is related to increase of particles size of the ash, which, with a surface deposition of mercury on ash grains, is in line with a reduction of surface area to grain weight ratio [10, 11].

Conducted research and implementations on mercury removal from flue gases indicate the possibility of reducing their content in coal combustion products, at least by 70 %, which should be unique with reduction in mercury content in the fly ashes.

New properties of fly ash and slags are discovered as they are milled to powders with a grain size of the order of nanometers (10-9 m), which is associated with the destruction of the existing structure of grains and often release of components to molecular form. In nano-ashes due to their fragmentation, the amount of grains and their surface and chemical reactivity increases, thus gaining new characteristics and functions. Nano-materials found a wide application as: carriers of drugs and catalysts, polishing agents, fillers for rubber and plastics and as raw materials for manufacturing of new materials with highest resistance etc. When added to concretes they positively influence on the properties.

The example of research may be an attempt for obtaining a new filler by means of milling, using ball mill, of fly ash with graining of 60 µm and specific surface area of 0.249 m^2/g. As a results of 405 hours of milling, the filler of graining of 148 nm and specific surface area of 25.53 m^2/g was obtained [12]. Polymer nano-composites with nano-ashes demonstrated, among others, higher resistance to radiation, lower flammability and time delayed ignition.

Nano-technologies also allow for extraction of metal oxides and aluminum oxides as well as active carbon from ash aluminosilicates; methods taken into consideration provide an increase of aluminum/silicon ratio from 0.86 to 1.63 [13, 14].

Nano-technologies are the future development methods of rational management of fly ashes and slags. Currently, these technologies are very energy-demanding and, from the point of protection of living organisms, they require special precautions.

Proposals of technologies increasing possibilities of management of CCPs.

The analysis of CCPs management and need of change of the existing market as well as reduction of carbon footprint (CO_2 emissions) indicate on desirability of increasing the production of certain existing products and on the need of launching new products on the basis of combustion products. First group contains increase of cenospheres recovery from fly ashes, increase of production of activated ashes and ash fertilizers. In the second group, it is appropriate to consider a purposefulness of specific ashes (with specific grain composition), hydrophobized ashes, metals concentrates etc.

Cenospheres are on the most valuable products obtained from fly ashes, which are in great demand as a thermal insulating material, light sinker bar, plastics filler, light concretes and building materials, abrasive materials, catalyst carriers and plant protection.

In the country, recent years ,in terms of extraction and enrichment of cenospheres from fly ashes, few important changes have been noted [15]. Currently, cenospheres are produced in many countries, with China, Russia and Kazakhstan as the biggest producers. In these countries, research and implementation resulted in rich knowledge of cenospheres [3, 16, 17]. Generally it can be said, that the cenospheres are produced in hydro-transport technology and storage of fly ashes, ash-slag mixtures and/or slags.

Management improvement of dry fly ashes significantly decreased raw material base for cenospheres production due to reduction of the amount of ash deposited on wet landfills, and in many cases, complete exclusion of ash landfills. In this situation, the existing methods for extracting and refining the cenospheres are insufficient.

Analysis of physico-chemical properties of fly ashes and cenospheres (content, graining, density, aerodynamic properties) shows fundamental differences, which in relatively easily manner can be used for secretion, processing and preparation of few sorts of cenospheres from dry fly ashes [18]. In addition, it is advisable to also analyze the recovery of cenospheres from deposits excluded from operation.

Activated ashes.

Increasing the chemical and hydraulic activity of fly ash has been known for many years and partially used in our country [19, 20]. The forerunner of this technology was prof. A. Paprocki, but then in our country he met with great opposition of our specialists, and simultaneously great recognition abroad [21].

Two activation methods can be distinguished:

- Surface, consisting in revealing aluminosilicates' grain surface and breaking up larger agglomerates of grains, that practically do not cause any harm to ash grains;
- Volumetric, consisting in breaking up the structure of ash grains into smaller grains.

Regardless of the method used, the activated ashes demonstrate higher fineness, increased specific surface area, chemical reactivity improvement including hydraulic properties and increase of the flow resistance of liquid media. The effect of fly ash milling in a jet mill on its physico-chemical properties is shown in Table 1 [22]. In contrast, surface activated ashes exhibit better rheological properties in gaseous and liquid environment (very important characteristic for concretes).

The use of mechanical activation of ashes allows to, inter alia, increase the degree of their conversion in fluidized beds and decrease the consumption of limestones. Application of activated ashes in concretes

Tab. 1 Physico-chemical properties of fly ashes activated in a jet mill and their influence on the resistance on standard cement mortars [22].

Tab. 1 Właściwości fizykochemicznych popiołów lotnych aktywowanych w młynie strumieniowym i wpływ ich na wytrzymałość na ściskanie zapraw normowych [22]

L.p.	Properties	Units	Initial fly ash	Fly ash mechanically activated in a jet mill of efficiency, kg/h			Standard mortar of 100% cement
				100	200	300	
1.	Specific surface area by Bleine	cm^2/g	1.743	5.404	5.140	4.674	-
2.	Pozzolanic activity coefficient „K”*:	%	106	195	187	137	-
3.	Resistance on standard mortar compression, in which 30 % of cement was replaced with fly ash:	MPa					
	- after 7 days		12,1	16,9	15,9	17,2	16,4
	- after 28 days		17,0	25,7	21,9	25,2	20,2
	- after 90 days		27,4	39,6	39,2	39,3	32,6

„K”*= ratio of compressive strength after mortar infusion, in which 30 wt% of cement was replaced with fly ash, and compressive strength after mortar infusion, in which 30 wt% of cement was replaced with sand. Activity evaluation: K > 170 % very active; K = 130 – 170 % active; K < 130 % weakly active

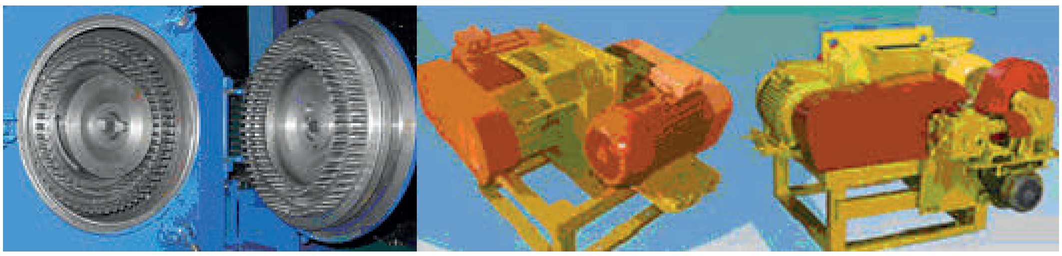

Fig. 2 Impact-rod mill for mechanical activation of fly ashes.
Rys. 2 Młyny udarowo-palcowe do aktywacji mechanicznej popiołów lotnych

helps to reduce cement consumption and obtaining the concretes of higher quality (tightness, resistance to chlorides and sulfates); once they are applied to binders production, they assure additional increase of binding properties; when they are applied for chemical neutralization of sewage/waste and/or de-oiling of the environment, they contribute to the desired effect. Surface activation of ashes and creation of very fine fly ashes having active properties is guaranteed by milling in the vibrating mill [20].

Extensive dissemination of activated ashes production is created by using impact mills, which have small dimensions and low power consumption when compared to tumbling-ball mills – Figure 2.

Activation in impact mills not only involves mechanical breaking of grain structure, but also consists in heat treatment, since the process is accompanied by occurring heat release and serious increase of temperature in the phase of broken grain. In this respect, interesting results have been obtained in Russia by activation of expired cement and metallurgical slag in impact mill [23, 24]. Activation method by means of impact mills is suitable not only for fly ashes, but also for their mixing with slag derived from current production and storage area.

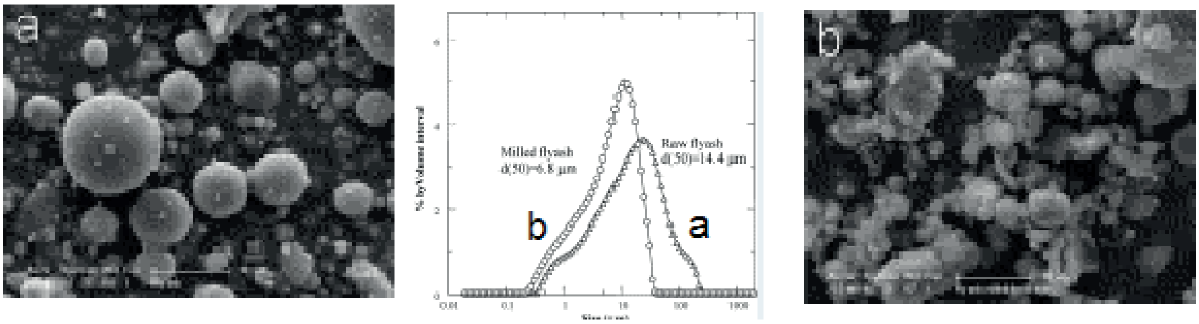

Fig. 3 Grains of fly ash before and after milling and particle size curve character [25].
Rys. 3 Ziarna popiołu lotnego przed i po przemiale oraz przebieg krzywych uziarnienia [25]

The group of these processes should also include technologies of manufacturing of geopolymers, which consists of fly ashes milling and treatment with alkalis. The appearance of grains of ash before and after milling as well as particle size curves character is shown in Figure 3.

Treating milled ashes with sodium hydroxide (NaOH), sodium silicate (water glass) and water causes formation of polymer Si-O-Al. that is characterized with high resistance parameters. Depending on the composition and conditions of the polymer formation, products reaching resistance of 40 MPa can be obtained, when non-processed demonstrated resistance of 16 MPa [26, 27]. Properties of geopolymers are also significantly affected by composition of raw material mixtures, temperature and time of conditioning [27, 28].

One of the interesting attempts to activate calcium ashes with simultaneous hydration in a flue gases current was undertaken in cooperation between Ekotech Inżynieria Popiołów and Rafako S.A. Technology is in the research stage, but if the results will be favourable, it can be a breakthrough in area of enrichment of ashes containing high amounts of limestone for application in concretes.

Lime-sulfur fertilizers.

Fly ashes from combustion of coal from Konin and Belchatow regions have been and are seen as very useful lime and lime-magnesium fertilizers [29, 30, 31]. Past use of lime ashes in confrontation to their properties and agriculture demands should be considered as insufficient.

Once we dispose lime ashes and ashes from fluidized beds, there are conditions for production of lime-sulfur fertilizers, which have drawn attention recently. Ash fertilizers should be granulated, according to trends in agriculture.

In recent years, fertilizers on the basis of synthetic gypsum and magnesium dope appeared on the market and are effectively sold. The teams working on fertilizers, prepare the conditions for application of ashes from combustion of biomass and ammonium compounds from anthropogenic sources. The remaining challenge are cheap technologies, granulation and ensuring regularity in deliveries. A serious obstacle in the development of this direction can be differences in the points of view of science world, among others, application of gypsum for soil improvement and fertilization.

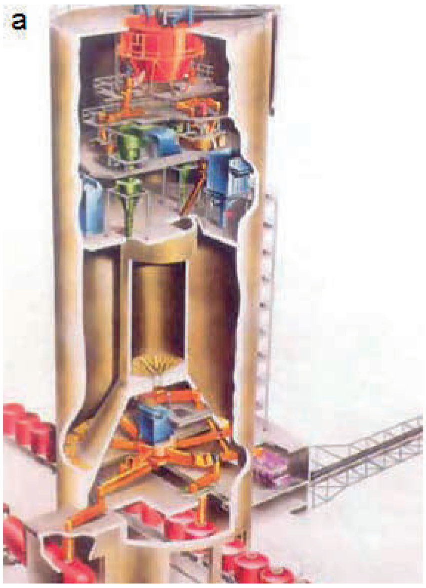

Fig. 4 Installations for fly ashes classification and quality ashes production
a) Bateman's typical installation for classification of fly ashes blended into storage stations, implemented at power plants in Lethabo and in Hong Kong;
b) The Ulula Ash plant at Kreil power station, South Africa

Rys. 4 Instalacje klasyfikacji popiołów lotnych i produkcji popiołów kwalifikowanych
a) typowy projekt firmy Batemann instalacji klasyfikacji popiołów lotnych wkomponowanych w stacje ich składowania, zrealizowany w elektrowni w Lethabo i w Hong Kongu;
b) The Ulula Ash plant at Kreil power station, South Africa

Quality ashes.
Under this name hide fractions of fly ashes of certain graining limits. The concepts of classification of fly ash have been already studied in many countries in the 70's, while the industrial scale production of the quality ashes was implemented in Republic of South Africa [32].

In recent years, the annual production of quality ashes has exceeded 3.5 million tons, only one power plant Kendal Power Station in Mpumalanga produces quality ashes in the amount of 1.2 million tons/year. Quality ashes are produced during transport and storage of fly ashes mixture in the power plants by installation of air separators – Figure 4. [33, 34, 35].

Ash Resources Pty company [35] produces quality ashes of following basic characteristics:
- Dura- Pozz : fly ash of 0.45 μm, which meets the requirements of EN 450;
- Dura- Pozz ® Pro ™ : fly ash Dura- Pozz containing more than 25 % of the grains less than 5 μm;
- Super- Pozz : highly reactive pozzolan alumino-silicate with an average grain size of

Tab. 2 Examples of the use of fly ashes in the concretes on the largest construction sites [38].

Tab. 2 Przykłady zastosowania popiołów lotnych w betonach na największych budowach [38]

PROJECT	Year(s)	Location	Combination, %	Strenght, N/mm^2	Main Requirement
Pacific First Centre	1989	United States of America	PC/FA9/SF6	124/56 day	Ultra hight long-term strength
Petronas Twin Towers	1995	Malaysia	PC/FA18/SF10	80	High early and long-term strength
Tsing Ma Bridge	1997	Hong Kong	PC/FA25/SF5	50	Chloride / permeability resistance
Storebaelt Crossing	1998	Denmark	PC/FA10/SF5	-	Chloride / sulfate / freeze-thaw
Bandra Worli Sealink	On-going	India	PC/FA25/SF7	60	Chloride in Marine exposure
Burj Dubai	2004–2009	United Arab Emirates	PC/FA25/SF7 PC/FA13/SF10	60 80	Chloride / sulfate / Strength / workability

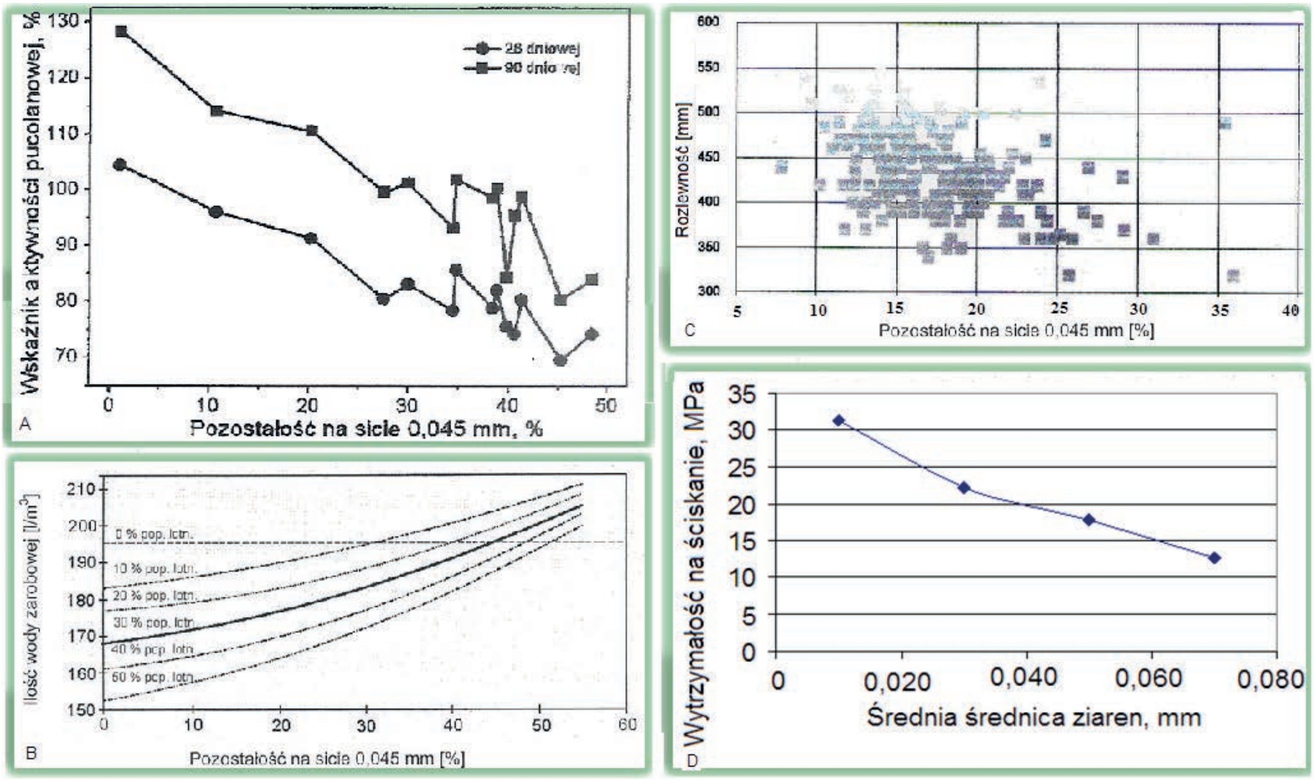

Fig. 5 Effect of fineness of fly ashes on their pozzolanic activity and properties of concretes.

Rys. 5 Wpływ miałkości popiołów lotnych na ich aktywność pucolanową i właściwości betonów z ich udziałem.

45 000 m^3 – amount of concrete used for foundation. SCC concrete 80 and C 60 = quality cement + local aggregate; ash content up to 300 kg/m^3 of concrete, c:w = 0,32; 330 000 m^3 is a total amount of concrete used for skyscraper construction.

Fig. 6 The picture of the highest skyscraper in the world being under construction, where quality ashes were used.

Rys. 6 Zdjęcie najwyższego drapacza chmur świata w czasie budowy gdzie stosowano popioły kwalifikowane

20 μm;

- Pozz -Fill : The grain fraction with an average grain size of 5 μm, characterized by a large hydraulic activity ;
- PlasFill 5: filler for rubber, plastics and paints with an average grain size of
4 μm;
- PlasFill 5-45 : filler for rubber and plastics with a grain size of 5 to 45 μm.

Strong interest in fly ash results from the knowledge of positive influence of ashes fineness on concretes properties, including: mechanical resistance, reducing the amount of batched water, increase of resistance to chloride and sulfate corrosion, improved flow, rheological properties improvement etc., what is illustrated by the results of many authors – Figure 5 [36, 37].

These valuable properties of quality ashes enable the production of self-consolidating concretes (SCC) and high strength concrete, including concretes of favorable rheological properties used in construction of skyscrapers – Table 2 [38, 39]. Even more interesting results are noted on the building site of Freedom Tower in New York, where decarbonized ashes were used as well as BASF fluxing agent.

Figure 6 is an example of the application of quality ashes on the construction site of the highest building in the world (828 m) - Burj Khalifa Tower in Dubai [40].

Conducted recognition of the problem and preliminary studies indicate the ability to run in Poland, in an industrial scale, the production of the quality ashes [41]. Currently, we dispose of raw material that have proper grain composition with a small content of unburned matter and high pozzolanic activity and research and development centers, which may determine the conditions and benefits of using quality ashes for construction purposes as well as products requiring fillers.

Hydrophobized fly ashes. In the 60's – 80's of the last century, the research and implementation works have been conducted and hydrophobized fly ashes were produced in a small scale. Hydrophobicity of the ashes was obtained by their surface impregnation in elevated temperature with mineral oils, mazout and silicones [42].

Hydrophobized fly ashes do not accept water, do not mix with water, "repel" the water and easily mix with oils etc. Such ashes have been and may be applied to: isolate buildings foundations, make hydroisolating belts and layers in hydrotechnical and engineering constructions, protect heating pipelines from corrosion and heat losses, roofing so-called "floating roofs" etc. One of the advantage of this direction of application of ashes is simple technology of their hydrophobization and large deliveries capacity.

Metals concentrates. Past Polish good experience in the field of power industry in production of metals concentrates (Fe_2O_3, GeO_2 and Al_2O_3) require verification and development of new tools for their recovery, keeping in mind, that we are facing rich ash deposits from current production and storage area [43, 44, 45].

The current level of electronics and technology of manufacturing of many elements and devices requires use of many hard to reach metals and their compounds. Unfortunately, for many of them there is a lack of resource base and, often through segregation of burned coals and ashes can be a source of their origin [46]. But all of this requires basic research.

The process of fuel combustion and flue gas cleaning processes from the chemical, thermal and mechanical point of view is a process of enrichment and impoverishment of the content of the individual components (chemical compounds), which is confirmed by sampling combustion products in various places of the flue gas sequence.

Summary

Combustion of coal is not only a source of heat and electricity, but also gaseous and solid products/wastes. Conducted research and implementations turned the solid combustion wastes into precious material and widely applied products. The motivation of these actions were management, economic and ecological considerations. Recent period of time is connected to a new argument rise, that is related to reduction of carbon footprint (carbon dioxide emissions) by using CCPs, including decrease of using and production the materials generating CO_2 emissions.

Conducted analyses, research and implementation in the country and abroad indicate a great potential of enrichment of existing directions of CCPs management. Extension of existing development directions requires a creation of new conditions of economic interest of potential producers on the basis of proper funds targeting derived from fees and fines for the use of the environment and facilitating the access to various targeted measures.

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Streszczenie

Dotychczasowy stan zagospodarowanie ubocznych produktów spalania z energetyki należy uznać za duże osiągnięcia krajowych ośrodków badawczych i wdrożeniowych energetyki i użytkowników. Na uzyskane rezultaty duży wpływ miał i ma nowy system zagospodarowania ups polegający na powstaniu szeregu organizacji nie tylko transportu, ale także rozwoju nowych technologii ich zagospodarowania.

W okresie niepopularności i dokonywanych optymalizacji spalania paliw węglowych, co niejednokrotnie obciąża również popioły lotne, żużle i produkty odsiarczania spalin staje się koniecznym dalsze rozeznawanie ich właściwości fizykochemicznych i toksycznych oraz upowszechnianie uzyskiwanych wyników badań, ocen i wyników wdrożeń.

Dla zwiększenia zakresu dotychczasowych zastosowań celowym jest rozważyć możliwości masowego ich zagospodarowania do produkcji kwalifikowanych, aktywowanych i hydrofobizowanych popiołów lotnych. W zakresie wytwarzania wysokiej jakości produktów wskazanym jest natomiast rozwinąć prace nad wytwarzaniem mikrosfer w technologii suchej i koncentratów metali oraz mikro i nano wypełniaczy i nośników. W miarę upowszechniania zagospodarowywania zdeponowanych popiołów ze składowisk staje się możliwym uzyskiwanie dużych efektów ekonomicznych poprzez kompleksowe zagospodarowanie złoża.

Słowa kluczowe: uboczne produkty spalania, popioły lotne, żużle, produkty odsiarczania spalin, utylizacja stałych produktów spalania węgla, popioły kwalifikowane