UDC 662.613.1:621.311.22.001.5

P a r t 3

ASH AND SLAG HANDLING

3.2. Ash and slag handling systems at TPPs

3.2.3. Bottom ash/slag removal

3.2.3.4. Recirculation of bottom ash into the fly ash handling process and an overview on coal ash reutilization. A case study: Fiume Santo power station

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ABSTRACT

Magaldi Power S.p.A. has developed and installed the MAC-Magaldi Ash Cooler® system for dry extraction, cooling and handling of bottom ash from pulverized coal-fired boilers.

The MAR-Magaldi Ash Recycling system is an improvement of the MAC technology; it is a process to recycle dry bottom ash into the combustion chamber in order to turn it into fly ash.

The paper describes the first industrial application of the MAR system in a 2x320 MWe PC power station in Fiume Santo in Sardinia-Italy (owned by E.On Italia) and an overview about coal ash reutilization.

1. INTRODUCTION

In the last years the respect for the natural environment has emerged as the most serious sustainability issue for most of the power stations in the world. High rates of energy consumption and lack of space for safe disposal of huge volumes of solid, liquid and gaseous wastes generated by the Power Sector has triggered climate change that is potentially devastating to life on the plant earth.

Burning fossil fuels in power stations throughout the world is among the largest source of CO_2 emissions. Besides energy, a variety of by-products of different kind is also obtained from the combustion of coal, in particular fly and bottom ash, which are inevitable at coal-fired boilers due to the presence of refractory mineral matter and of some components of the fuel, the combustion of which is slower and incomplete.

International standards regulate the possible uses of coal combustion ash as a constituent of cement (EN 197-1:2000/A3:2007) and concrete (EN 450-1:2005/A1:2007). Therefore, instead of being considered a waste material, coal ash can be beneficially used and considered as a source of usable and valuable by-products that cost-effectively improves the quality of many building materials, while creating significant environmental benefits.

In order to reduce as much as possible these environmental impacts and to make ash usable in cement industry and concrete production, Magaldi Power S.p.A. has developed and patented a system able to extract, cool and recycle into the combustion chamber the furnace bottom ash.

This new system combines the advantages of the successfully field-proven MAC – Magaldi Ash Cooler® system and its development, called MAR – Magaldi Ash Recycling system, thus resulting in an integrated bottom ash handling system. The MAC system allows to extract, convey and cool down the bottom ash produced in a solid fuel fired boiler in a completely dry way (ambient air is the cooling medium instead of water), while the MAR system recycles dry bottom ash into the combustion chamber turning it into fly ash.

Among coal combustion products (CCPs), fly ash is highly effective in reducing the carbon footprints associated with the use of Portland cement clinker, which is the principle ingredient of modern cements.

In this paper, the patented MAR technology is described to demonstrate the actual performance conditions that have been achieved in Fiume Santo power station (owned by E.On Italia). The paper also gives a general overview on coal ash reutilization.

PATENTS

Patents related to the system are the following:

- "Steam generating system and method for discharge of ash", International Patent N° EP 471055 B1, priority IT 1955490 of March the 2nd 1990
- "Integrated system for the extraction of heavy ash, conversion thereof into light ash and reduction of unburned matter", Application Number PCT/EP 2005/007536, priority IT MI 2004 A 001371 of July the 9th 2004

2. THE MAR SYSTEM: THE FIUME SANTO PROJECT

2.1 Boilers technical data

In June 2003 two MAC-Magaldi Ash Cooler® systems were successfully installed under units #3 and #4 in Fiume Santo power station, owned by E.On Italia and located in a delicate natural environmental area in the North-Western part of the Sardinia island (Italy).

The dry systems brought significant advantages, giving solution to environmental problems by the elimination of any water for the bottom ash processing, thus providing the simplest and most reliable way to solve the problem of being in compliance with new stringent environmental regulations.

The units #3 and #4 in Fiume Santo power station have a 320 MWe nominal power each. The boilers are equipped with tangential burners and the six burner levels are fed by Raymond XRP 783 coal bowl mills, working at positive pressure.

Both units are fuelled with pulverized coal; provisions have also been made for future up-grade for biomass co-combustion. The coal fuelled in this power station has medium-high ash content (e.g. South African coal quality) with an average LHV of 6,000 kcal/kg. The total combustion air is on average equal to 1,200 t/h.

2.2 Bottom ash data

The furnace bottom ash density is assumed to be 700 kg/m^3 for volume calculations and 1,400 kg/m^3 for structural calculations.

The bottom ash grain size distribution downstream the MAC system is not constant, depending on the secondary mill pulverization efficiency. The assumed ash grain size distribution is: 10,54 %< 1,18 mm and 100 % < 5,0 mm.

The maximum bottom ash rate is estimated to be approximately 1,84 t/h @ MCR, assuming a maximum ash content in the coal of 16% and a bottom/fly ash split of 10/90 %. Following Table 1 summarizes the main fuel data and the ash rates.

Table 1. **Fuel and Ash Data**

FUEL AND BOTTOM ASH DATA			
Coal input to the boiler @ MCR		t/h	115
COAL	Ash content	%	12,0
		%	16,0 *(max)*
	LHV	MJ/kg	25,0
ASH	Total ash	t/h	~ 18,4
	Bottom Ash Rate	%	10
		t/h	~ 1,84 *(normal)*
		t/h	6 *(sootblowing)*
		t/h	9 *(design)*
ROLLER COAL MILL	Type	-	Raymond
	Number	-	6 *(1 standby)*
	Overpressure	mmH_2O	300 *(normal)*
	Coal Feed Rate	t/h	40 *(nominal)*
		t/h	32 *(max set)*
		t/h	23 *(normal)*
BOTTOM ASH RECYCLED	Number of mill receiving recycled b.a.	-	4
	Bottom ash rate per mill	t/h	0,46
	Mill rate increase	%	2,0 *(normal)*

2.3 The MAR system technical specification

The MAR system installed in Fiume Santo power station includes the following components:

- A positive pressure pneumatic conveying system with basalt lined pipes. The pneumatic conveying system feeds, by means of a diverter valve, the reception bins which have been installed at 18 meters elevation;
- Two reception bins which temporarily store bottom ash to be recycled into the boiler. Those bins are loaded from the top by means of a dedicated valve. The bin venting air is directly connected to the combustion chamber at 35 meters elevation. Each bin is provided with two separated discharge ducts, one per single coal mill;
- Four vibrofeeders (two per each reception bin) which dose the recycled bottom ash in the coal mills. The ash feed rate dosed in each coal mill is automatically adjusted accordingly the corresponding coal feeder rpm;
- Four pneumatic knife-gate valves, installed at each vibrofeeder discharge point;
- Two pneumatic ball valves, installed on each bin venting in order to seal the reception bins from the combustion chamber.

Figure 1 shows the flow-diagram of the bottom ash recycling system installed in Fiume Santo power station.

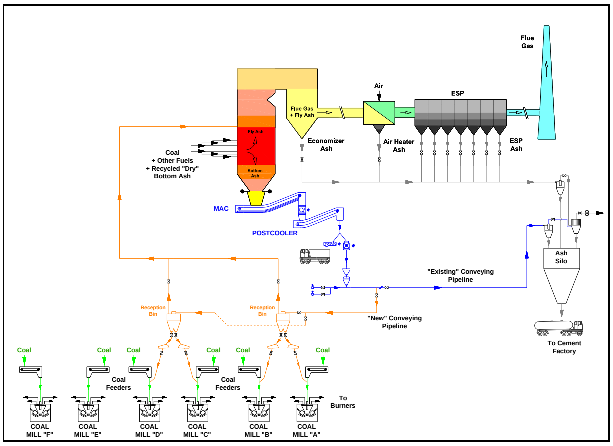


Fig. 1. The Magaldi Ash Recycling system flow-diagram

2.4 The pneumatic conveying system

The positive pressure pneumatic conveying system had previously been installed in 2003 downstream the MAC dry bottom ash extraction system.

In order to recycle the pulverized bottom ash through a new conveying line a junction has been designed on the existing pipe route to the fly ash silo (see Fig.1). The logic control system is able to manage two operating modes:

1. Pulverized bottom ash conveyance to the fly ash silo for final mixing and storage;
2. Pulverized bottom ash recycling in the combustion chamber by the MAR system, in order to valorise bottom ash turning it into valuable fly ash.

The new pipe line, due to the presence of a high abrasive material such as the coal ash, has been internally lined with high wear resistant material. In case of the recycling line is selected, bottom ash is pneumatically conveyed to the reception bins located at 18 meters elevation. Figure 2 shows the conveying line and location of the reception bins in the boiler house.

2.5 Reception bins

In each reception bin the recycled ash settles on the bottom while the finest particles are conveyed by the transport air to the combustion chamber. Bottom ash is extracted from the reception bins by means of tubular vibrofeeders and discharged directly in the coal mill feeding hoppers. A single reception bin serves two coal mills, so that it has been necessary to install two vibrofeeders per each reception bin; each reception bin has also been provided with a bursting disc for emergency relief and with four level probes.

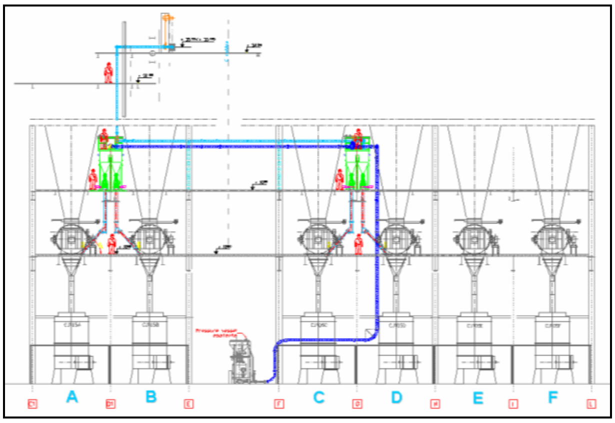


Fig. 2. Ash conveying pipe route

The reception bins provide a simple bottom ash classification by granulometry in order to ensure that only the fine particles will directly be injected in the combustion chamber (see Fig. 3).

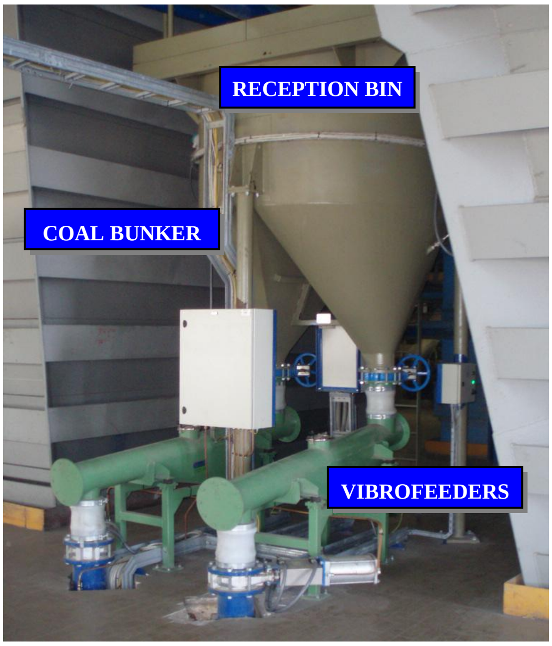


Fig. 3. Reception bin located between the coal bunkers

For each single reception bin the conveying air of the pneumatic system is fed in the boiler through an inspection door installed at 35 meters elevation. The pipe cross section has been chosen in order to ensure a high flow speed necessary to avoid any ash settlement in the pipe and a suitable inlet speed in the combustion chamber.

2.6 Vibrofeeders

The vibrofeeders are four in total. The logic control system adjusts the dosed ash rate as a function of the actual coal feed rate in the combustion chamber. This control system allows to maintain as fixed as possible the ash/coal ratio to the coal mills.

The coal and recycled bottom ash mix, after coal mill pulverization, is conveyed by the primary air to the coal burners and then injected in the combustion chamber.

The pulverized bottom ash finally turns into fly ash.

3. FUNCTIONAL DESCRIPTION OF THE MAR SYSTEM

During start-up operations the MAR system runs in manual mode in order to allow the build up of a minimum ash layer in the reception bins. This occurrence must carefully be evaluated in order to ensure the proper separation between the positive pressure equipment (coal feeders and coal mills) and the other ones at a negative pressure (combustion chamber). In steady operating conditions the recircula-ted bottom ash layer in the reception bins is kept constant by means of two low level probes. The reception bin loading is, on the other hand, controlled by two high level probes.

Each reception bin has two unloading points with dedicated vibrofeeders for bottom ash dosing in the coal mills. As result of the logic control system action on ash discharge, the ash rate dosed in the coal mills is a function of the corresponding coal feeder speed (rpm).

When both reception bins are running, the following operating conditions can occur:

- One coal mill unavailable: bottom ash recycling by three coal mills;
- Two coal mills unavailable: bottom ash recycling by two coal mills (this operating condition should last as short as possible in order to reduce the coal mill wear phenomena).
- Three coal mills unavailable: bottom ash recycling is not possible and bottom ash is pneumatically transported to the fly ash silo.

Thanks to the automation system the bottom ash recycling can be performed according to one of the three above mentioned conditions.

The bottom ash rate for a coal mill is adjusted by the corresponding vibrofeeder in a complete automatic mode. Once calculated the bottom ash rate to be recycled, a suitable control signal is sent to the vibrofeeder. Fig. 4 shows a typical vibrofeeder characteristic curve.

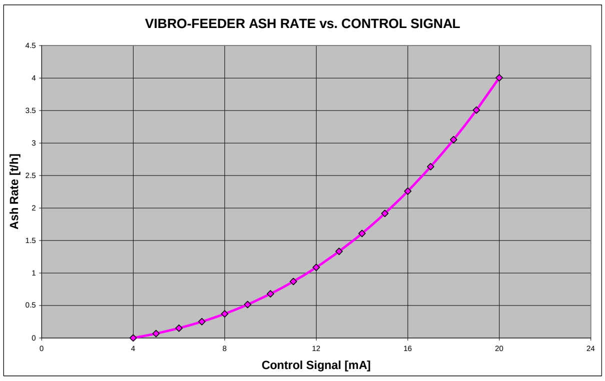


Fig. 4. Vibrofeeder ash rate vs. Control signal

3.1 Coal mill wear: field tests results

After the MAR system installation in Fiume Santo power station, some experimental activities have been carried out in order to evaluate the actual coal mill wear rate.

As said before, each boiler is equipped with six Raymond XRP 783 coal bowl mills operating at positive pressure (one coal mill is always in stand-by) and with a tangential firing system. Only four out of six coal mills are receiving recycled bottom ash.

The dimensional inspection on the coal mill wear components is normally scheduled every 2.000÷2.100 operation hours; such inspections concern bowls, grinding ring and the coal mill classifier. At the end of each observation period, the dimensional deviation due to the wear has been evaluated by means of a roll template. Moreover each grinding roll has been weighted in order to measure the weight loss. Figure 5 shows the numerical results of the above mentioned experimental phase after almost two years with the MAR system in steady operating conditions.

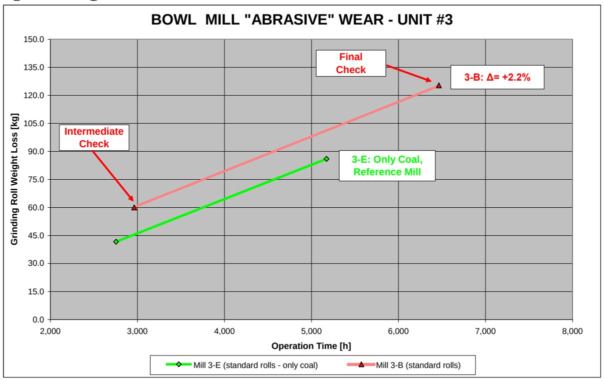


Fig. 5. Bowl mill abrasive wear results

These results show that the wear rate is between 2…3 %. The mentioned wear rate deviation has been observed with a bottom ash average rate of 1,0 t/h, meaning an ash/coal ratio approx. of 1,0 % on each coal mill. Moreover, the checks carried out on the coal mill classifiers have shown no appreciable wear differences. The same remark can be done on the boiler burners after the preliminary going-over in January 2008. Regarding the pulverized coal feeding line to the boiler, there is no significant difference between the measured wear and the expected one.

4. FLY ASH CERTIFICATION

The implementation of the MAR-Magaldi Ash Recycling system in Fiume Santo power station has also successfully achieved another important challenge demonstrating there has been no impact on the fly ash properties due to the bottom ash recycling into the boiler.

Fly ash collected after the commissioning of the bottom ash recycling system is in full compliance with the European standard EN 450-1 and it is certified as a valuable by-product for cement and concrete industry.

Therefore after the MAR system installation bottom ash has not to be considered any more a coal combustion waste material but a valuable by-product since it has been completely turned into fly ash.

In 2007, in order to achieve the mentioned product certification, the power plant certified its entire manufacturing processes from the coal ship unloading to the fly ash delivery to final customers (UNI EN ISO 9001).

During the first three months the quality procedures led to perform complete chemical and physic analyses whose results are briefly shown in the following tables 2 and 3.

Table 2. **Fly ash chemical analysis**

CHEMICAL ANALYSIS SPECIFICATIONS		
ELEMENT	LIMIT	LIMIT DESCRIPTION
Loss On Ignition (LOI)	Category A: < 5,0% (*) Category B: 2,0%÷7,0% (*) Category C: 4,0%÷9,0% (*)	Ranging value
Chloride	0,10% (*)	Max value as Cl^-
Sulphuric anhydride (SO_3)	3,0% (*)	Max value
Free calcium oxide	2,5% (*)	Max value
Reactive calcium oxide	10% (*)	Max value
Reactive silicon dioxide	25% (*)	Max value
Silicon dioxide (SiO_2), aluminium oxide (Al_2O_3) and iron oxide (Fe_2O_3)	Sum 70% (*)	Max value
Alkalis	5,0% (*)	Max value
Magnesium oxide (MgO)	4,0% (*)	Max value
Soluble phosphate (P_2O_5)	100 mg/kg	Max value

Notes: (*) by mass

After the observation period a statistical results analysis has been done according with the following specifications:

- Sampling for the third part (certification body) check;
- First quality audit by the third part (certification body) for process analysis;
- Temporary certification based on declared results;
- Certificate validation after further check;
- Continuous monitoring activity for statistical analysis.

Table 3. **Fly ash physical analysis**

PHYSICAL ANALYSIS SPECIFICATIONS		
CHARACTERISTICS	LIMIT	LIMIT DESCRIPTION
Fineness	Category N: 40% oversize(*); ± 10% variation limits from the declared value Category S: 12% oversize (*)	Maximum value on a 0,045 mm mesh sieve
Activity Index	75% at 28 days, 85% at 90 days	Minimum value
Soundness	10 mm	Max value

Density	± 200 kg/m^3	Max deviation from the value declared by the producer

Notes: (*) by mass

An extensive analysis activity in compliance with the quality standards has demonstrated that the fly ash properties have not been influenced by the MAR system implementation.

The fineness of fly ash is expressed as the mass proportion in percent of the ash retained when wet sieved on a 0.045 mm mesh sieve (determined in accordance with EN 451-2) and has to fall within the limits of the categories specified in UNI EN 450-1.

The next figures 6 and 7 show the fineness and the UBC content monthly trends of the above mentioned activity before (April 2007) and after (May 2008) the MAR system implementation.

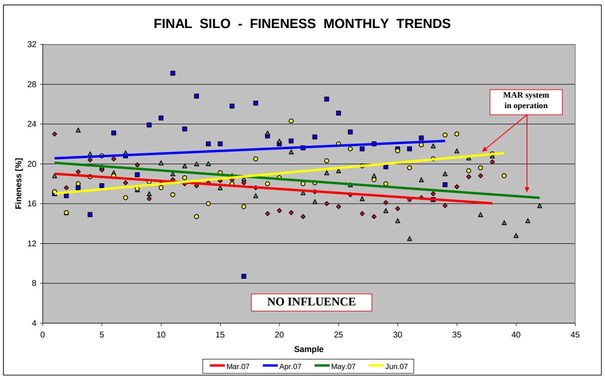


Fig. 6. Fineness monthly trends (before and after the MAR system implementation)

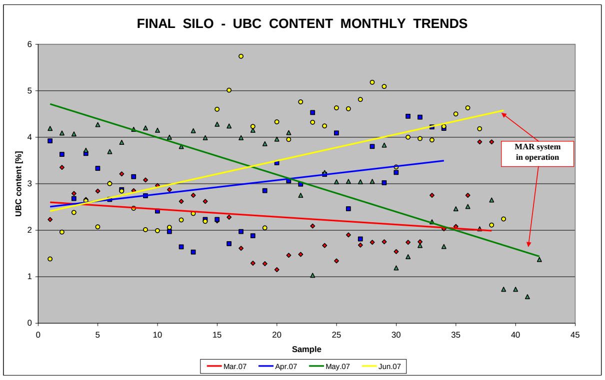
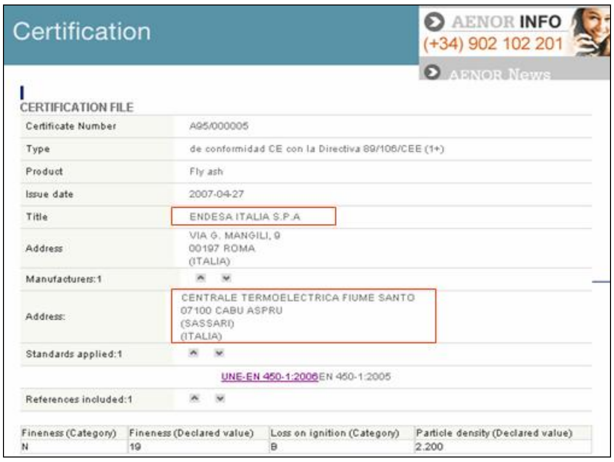


Fig. 7. UBC content monthly trends (before and after the MAR system implementation)

Figure 8 there is the fly ash certificate obtained by E.On Italia for Fiume Santo power plant in full compliance with the European standard UNI EN 450-1.

Fly ash in Fiume Santo power station has been classified with the following characteristics:

- Fineness:
  category "N" (max 40 % by mass > 0.045 mm).
- Fineness declared value:
  19 % (±10% variation limits).
- Loss on Ignition (LOI):
  category "B" (2…7% by mass).
- Particle Density:
  2.200 kg/m^3 (±200 kg/m^3 variation).



Certification

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CERTIFICATION FILE

Certificate Number	A95/000005
Type	de conformidad CE con la Directiva 89/106/CEE (1+)
Product	Fly ash
Issue date	2007-04-27
Title	ENDESA ITALIA S.P.A
Address	VIA G. MANGILI, 9 00197 ROMA (ITALIA)
Manufacturers:1	
Address:	CENTRALE TERMOELECTRICA FIUME SANTO 07100 CABU ASPRU (SASSARI) (ITALIA)
Standards applied:1	
	UNE-EN 450-1:2006EN 450-1:2005
References included:1	

Fineness (Category)	Fineness (Declared value)	Loss on ignition (Category)	Particle density (Declared value)
N	19	B	2.200

Fig. 8. EN 450-1 Fly ash certificate

4.1 Results of the Fiume Santo Project

The implementation of the MAR-Magaldi Ash Recycling system in Fiume Santo power station has given the following main results:

1. The bottom ash recycling in the coal mills has a negligible impact on coal mill wear rate;
2. The pulverized bottom ash conversion into fly ash increases the fly ash quality and quantity; as a matter of fact there is a UBC (UnBurnt Carbon) content reduction thanks to the dilution effect of bottom ash which has a very low unburned carbon content;
3. The bottom ash conversion into fly ash has no negative impact on fly ash properties leading to a bottom ash valorization from a coal combustion waste into a valuable by-product;
4. Indeed, the fly ash production is increased by the bottom ash recycling certified CE according with European standards which means no-restriction carriage through EU member states.

5. OVERVIEW ON COAL ASH REUTILIZATION

The subject of coal combustion products (CCPs) reutilization is covered by numerous publications and a lot of organizations and government agencies world wide continuously promote the sustainability of the concrete industry by coal ash utilization. The aim of this section is simply to provide an overview of the main fields of application for the CPPs, in particular of fly ash.

Every year huge quantities of potentially usable by-products of coal combustion are obtained in thermal electric power stations.

The use of ash as a building material is not new. More than 2.000 years ago – long before the invention of Portland cement – the Romans used volcanic ash to construct magnificent structures that are still standing today, such as the Pantheon in Rome. Modern interest in using coal fly ash as a cementitious product began in post-war Europe. By the 1950s and '60s, power plants in the United States were collecting their fly ash and creating a number of beneficial uses.

Fly ash can be used in a variety of structural and low strength fill applications. It can be used as mineral filler for paints, shingles, carpet backing and other products. It can be used in manufacturing mortars and stuccos. It even has various agricultural applications. But the largest application for fly ash is in the production of Portland cement and concrete.

Typically, ordinary Portland cement is composed of 95% clinker and 5% gypsum. Gypsum is known as a complementary cementing material because it enhances the cement performance by improving the setting and hardening characteristics of the product. In addition to gypsum other mineral additives, commonly known as supplementary cementing materials can either be interground with clinker and gypsum or added directly during the concrete mixing operation.

Concrete, the most common building material in the world, is primarily a mixture of aggregates (rock and sand), cement and water. Compounds in the cement react with water to form a glue that binds the sand and rock into a hardened mass.

5.1 Main target: reducing the CO_2 emissions

In Portland clinker manufacturing process, direct release of CO_2 occurs from two sources, namely the decomposition of calcium carbonate (the principal raw material) and the combustion of fossil fuels. The former accounts for about 0,6 kg CO_2/kg clinker and the latter 0,25-0,35 kg CO_2/kg clinker, depending on the carbon content of the fossil fuel; therefore, the global average now is 0,9 kg CO_2/kg clinker. Alternate sources of energy other than fossil fuels are being sought but, at present, they are too expensive. Also, there are some cements that do not require calcium carbonate as a raw material (e.g. magnesium phosphate cements) but they are neither economical nor technically feasible for large-scale production.

The annual rate of cement consumption in the world has nearly doubled during the last 15 years and the magnitude of the problem of global CO_2 emissions directly attributable to clinker production becomes at once clear.

Therefore, a long-term strategy for sustainability of the concrete industry is necessary.

When used as a complementary cementing material, each ton of fly ash can replace a ton of Portland clinker. Moreover, when fly ash is added to the concrete mix, some of the cement can be eliminated. The result is concrete that is more durable and stronger over time than concrete made with cement alone. When fly ash is added to concrete, it reacts with calcium hydroxide and forms stable hydrates of calcium silicate and calcium aluminate. The resulting concrete is not only stronger and more durable, but also less permeable. This makes concrete more resistant to chemical attack. The reduction of the penetration of chlorides as well as the sulphate resistance of concrete are improved by using fly ash. The addition of fly ash to mass concrete is important to reduce crack formation due to the low hydration heat. The particles of fly ash are small and spherical – allowing them to fill voids and provide a "ball-bearing" effect that allows less water to be used, thus improving the work-ability and flow characteristics of concrete. Additionally the fly ash improves the grading curve of the concrete mixture. These features have a significant effect on water demand, and result in less water being used.

Therefore, increasing the utilization of most of the available fly ash as a complementary cementing material or using it in concrete production is, unquestionably, the most powerful tool for reducing the environmental impact of the two major sectors of our industrial economy, namely the cement industry and the coal-fired power industry. Moreover, fly ash use preserves natural resources by replacing materials that would otherwise be mined to manufacture cement.

Sustainable Portland-clinker based cements can be made with 0,5 or even lower clinker factor using a high volume of granulated blast furnace slag (gbfs) or coal fly ash or a combination of both. Natural or calcined pozzolans, in combination with fly ash and/or gbfs, may also be used. Compared to Portland cement, the high-volume fly ash and slag cements are somewhat slower in setting and hardening, but they are more suitable for producing highly durable concrete products. Unfortunately, worldwide, the conventional concrete construction practice is dominated by prescriptive specifications that do not permit the use of high volume of mineral additives.

The European Cement Specification EN 197/1, issued in 2006, contains 26 types of blended Portland cements including three cement types that have clinker factors ranging between 0,35 and 0,64. Type III-A Cement covers slag cements with 36-65 % gbfs; Type IV-B Cement covers pozzolanic cements with 36-55 % pozzolans such as fly ash, natural or calcined pozzolanic minerals, and silica fume; Type V-A Cement covers composite cements containing 18-30 % gbfs plus 18-30 % pozzolans. According to Cembureau statistics for 2005, the consumption of ordinary Portland cement in the European Union countries has dropped to 30 % of the total cement produced, whereas blended Portland cements containing up to 25 % complementary cementing materials have captured 57 % of the market share, and blended cements with more than 25 % complementary cementing materials are approaching 10 % of the total cement consumption.

For reducing direct carbon emissions attributable to Portland clinker production, the emerging technology of *high-volume fly ash* (HVFA) concrete is an excellent example showing how highly durable and sustainable concrete mixtures, with clinker factor of 0,5 or less, can be produced by using ordinary coal fly ash, which are available in most parts of the world in large amounts. The composition and characteristics of HVFA concrete are discussed in many publications and are only briefly described below. Note that concrete mixtures with similar properties can be produced by using a high volume of granulated blast-furnace slag or a combination of fly ash and slag, with or without other mineral admixtures.

The cementing material in HVFA concrete is composed of ordinary Portland cement together with at least

50 % fly ash by mass of the total cementing material. The mix has a low water content (100-130 kg/m^3), and a low content of cementing materials (e.g. 300 kg/m^3 for ordinary strength and max. 400 kg/m^3 for high-strength). The plasticizing action of the high volume of fly ash imparts excellent workability even at w/cm of the order of 0,4. However, chemical plasticizers are often used, when lower w/cm are required. Occasionally, an air entraining admixture is also included in the mix when protection against frost action is sought.

Compared to Portland-cement concrete, the HVFA concrete mixtures designed to achieve the same 28-d strength exhibit superior workability without segregating even at slump values of 200-250 mm. Typically, the concrete is slow in setting and hardening, i.e. develop slightly lower strength at 3 and 7-d, similar strength at 28-d, and much higher strength at 90-d and 1-year. The pozzolanic reaction leading to complete removal of calcium hydroxide from cement hydration products enables the HVFA concrete to become highly resistant to alkali-aggregate reaction, sulphate attacks, and reinforcement corrosion (due to very low electric conductivity).

Furthermore, the HVFA concrete mixtures are much less vulnerable to cracking from both the thermal shrinkage (less heat of hydration), and the drying shrinkage (less volume of cement paste). Therefore, in addition to very low clinker factor, the ability of HVFA concrete to enhance the durability by factor of 5 to10 makes it a highly suitable material for construction of sustainable structures in the future.

6. CONCLUSIONS

The MAR-Magaldi Ash Recycling system is able to convert all bottom ash into sealable fly ash with a complete elimination of costs associated with bottom ash disposal. Moreover, it has been achieved an UBC content reduction in fly ash due to dilution effect. The bottom ash conversion into fly ash has no negative impact on fly ash properties thus leading to a bottom ash valorisation. Fly ash is in compliance with international standards (in Europe the EN197-1 for cement and EN 450-1 for concrete) and is certified CE according with European standards.

The bottom ash recycling in the coal mills has a negligible impact on coal mill wear rate.

A more severe approach concerning landfill of CCPs is coming on in several countries and many restrictions keep up with it. Consequently, in order to reduce and prevent the landfilling burden, as well as to increase the use and value of fly ash related to various applications, a beneficiation process becomes necessary. To this end the MAR system can be considered the right technology for the achievement of this goal, in order to increase the overall recovery of beneficiated ash and to obtain a by-product to be reutilized for cement and concrete applications.

ACKNOWLEDGMENTS

Magaldi would like to thank Fiume Santo power plant personnel for their kind availability in supporting Magaldi Power S.p.A. field activities.

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