Fly Ash Research at Technikon Pretoria, South Africa

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INTRODUCTION

South Africa has a large power generating industry and provides approximately 60 percent of the electric power generated on the African continent. Most of this is done in coal-fired power stations and consequently a huge amount of coal combustion by-products, and in particular fly ash, is generated in the process. South Africa currently produces about 30 million tons of fly ash per annum, of which nearly 1.2 million tons is used for different purposes. The largest consumer of fly ash remains the cement and concrete manufacturing industries, but significant amounts are also used by the polymer industry as a filler. Beneficiated fly ash produces very small spherical particles of uniform size called cenospheres that can potentially be used as a filler in various paints. Work at Technikon Pretoria is aimed at finding alternative uses for fly ash and assisting with the development and application of measurements for plant and quality control systems.

Technikons are part of the higher education tertiary training institutions in South Africa. They offer mostly career-focused education to graduates, in contrast to the broader technology training provided by universities. Due to changes over the last few years, Technikons nowadays are hybrid institutions somewhere between a traditional vocational school and an academic university. Technikons concentrate on applied research in contrast to the universities in South Africa that, in many cases, still pursue basic research. This creates an ideal environment to investigate all sorts of new and different applications for fly ash to try and find uses for this waste product. This short article will highlight a few of the projects currently underway at Technikon Pretoria.

MINING BACKFILL FORMULATIONS

Most applications of fly ash in South Africa, as well as the rest of the world, are in the cement and concrete production industries. However, it is also suitable to be used in collieries for stabilizing old board and pillar workings, either to facilitate extraction of coal in neighboring seams or to protect surface structures. Board and pillar extraction accounts for more than 50 percent of current coal production in South Africa. In such applications the “ashfill” serves to preserve the integrity of the pillars that have or could deteriorate over time and to prevent sudden pillar collapses.

In the existing practice, surface objects in mining areas are protected by leaving large blocks underground unmined, so that they can form protective pillars. Valuable minerals/coal are locked up in these protective pillars that could potentially be extracted by, among others, board and pillar workings and by filling it with high quality ashfill for support. To be suitable for backfill purposes, controlled collapse is required from the backfill material, rather than an exceptionally high final strength.

For most applications, Portland cement, sand and fly ash mixtures are used because of low cost and the reliability of strength gain. Compressive strength of the fly ash containing backfill increases with time and is largely dependant on the slurry concentration in which the ashfill was placed. A significant amount of fly ash is required in the backfill formulation to ensure good pump ability.

Work at Technikon Pretoria yielded promising results when using formulations containing 50 percent fly ash or slag in conjunction with lime as an activator and 5 percent Portland cement. Gypsum was used as a filler material in these mixes. The current investigation compared some of the costs of these formulations, as shown in Table 1.
The work conclusively showed that backfill formulations of sufficient strength and competitive prices could be produced by using fly ash. It was also found that mixtures made with fly ash were significantly cheaper than similar ones made with an equal amount of slag.

**TREATMENT OF A FERRO-INDUSTRY WASTE**

The combination of fly ash and cement with hazardous waste offers a number of novel ways to treat side product streams from several industries. These treatments are based on the solidification, immobilization and encapsulation of wastes through various physical, thermal and chemical mechanisms. South Africa is a major producer of various ferro-alloy raw materials, for example ferro-chrome, ferro-silicon and ferro-vanadium, to name but a few. These industries produce a number of waste products that can be potentially harmful to the environment and require treatment or controlled land filling to minimize their harmful effects.

Wastes combined with fly ash can be used as one option to immobilize harmful elements originating from the waste, after thermal treatment. However, a pre-requisite for this route of treatment, is that the cement raw mix’s ability to burn not be compromised by the addition of any foreign material. A further thermal treatment that renders waste harmless or at least decreases interaction with the environment is sintering with fly ash. Using this method it is possible to create useful products from the process, for example lightweight aggregates and ceramic filters/tiles.

The pozzolanicity of fly ash offers another route for the treatment of wastes. Together with a suitable activator, like lime, it can be mixed with the waste to harden in a solid cementitious matrix. In this way the potentially harmful elements present in the waste can be incorporated in a durable matrix which can present both a physical as well as chemical barrier against its contact with the environment. Should concrete be used to encapsulate waste of some form or another, the well documented ability of fly ash to adsorb heavy metal elements, which can potentially be present in an untreated waste, would certainly enhance the effectiveness of this proposed treatment option. In addition, the greater durability imparted by the fly ash to the final concrete element would further contribute to a reduced risk of potential leaching.

Work done at Technikon Pretoria using waste from a South African ferro-vanadium producer showed that by incorporating it into a variety of solid matrices, it can be successfully treated to be less harmful to the environment. At the same time, reasonable savings can be achieved in the cost of the products produced.

**FLY ASH IN PUTTY**

Putty is a fairly cheap product widely used to act as “glue” for fitting glass to frames. It is commonly prepared from any cheap limestone, mixed with raw linseed oil and “acid oil” before being applied as a soft amorphous mass. Being soft, it can be easily spread. Once exposed to sunlight, and more specifically UV light, it undergoes a reaction, probably polymerization of the organic component that leads to gradual hardening. Oxygen is essential for this polymerization reaction to occur. It is most probably the triglyceride component that reacts to polymerize, although the acidic part could also play a role in this phenomenon. The reaction could be exothermic, so care should be taken during storage to prevent possible fires. The reaction seems to be catalyzed by some alkalinity in the limestone. This catalysis can be linked to the reaction of the calcium cation and is known to occur in the thickening of paints as well through the catalyzing effect of heavy metal ions.
Fly ash and used cooking oil are two waste products that could possibly be utilized for the same purposes as limestone and raw linseed oil. This investigation concentrated on the interactions between these two materials in an effort to try and establish what kind of changes take place during the setting/hardening period. A typical spectrum is shown in Figure 1 that depicts the changes occurring during the evolution of the setting/hardening process.

It can be seen that some of the double bonds normally present in certain compounds present in the used cooking oil show signs of polymerization and that it is influenced by the presence of CaO in the sample. This project is still underway and it is hoped that more information will eventually be gathered to explain the process in greater detail.

PLANT CONTROL INVESTIGATIONS

Fly ash from the electrostatic precipitators of a power station is separated in two cyclones into a coarse and fine fraction in one of the Ash Resources plants in South Africa. An investigation is currently underway to assist the plant to develop a simple and robust method of controlling the particle size fractions coming from the cyclones. For this purpose a chosen weight of fly ash is placed in a cylindrical holder and rolled down a 15 degree incline onto a horizontal plane. The distance that the holder travels along the horizontal plane before it comes to rest, is a function of the mass of the fly ash placed inside the holder, the volume thereof and, most importantly, the particle size of the material. This latter property influences the flow of the fly ash inside the holder during the rolling action and determines the distance that the holder travels on the horizontal plane before it comes to rest. It is hoped that this work, which is still in progress, will result in a suitable method for unskilled operators to exercise plant control and regulate the operation of the cyclones employed for the fly ash separation.

CONCLUSION

From the short description above one can conclude that fly ash has many interesting potential applications and that a lot more work can be done on this exciting material. The projects mentioned give students the opportunity to investigate new and crazy ideas, while at the same time learning problem solving skills and the art of conducting research. As there is no other tertiary education institution in South Africa engaged mainly in research and development work on fly ash, it is important to nurture and encourage the work being carried out by the Materials Research Group at Technikon Pretoria. The group is currently involved in the publication of a book and accompanying CD together with the South African Coal Ash Association that will highlight the many applications of fly ash. It is hoped that this book, which will describe the chemistry of fly ash and its utilization in many potential fields, will become a useful reference in the future for all working with this exciting and unique material.

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CAER, LG&E Energy Launch Multi-Million Environmental Cleanup Project

The UK Center for Applied Energy Research (CAER) and LG&E Energy Corp. are partnering on a project to reduce the amount of landfill space needed to store ash from coal-burning power plants. CAER researchers will use $4 million in funds from the U.S. Department of Energy (DOE) to develop a facility at the LG&E plant in Ghent, Kentucky to turn coal ash into a cement substitute. LG&E put up $3 million of its own funds for the project, and UK $1 million.

“This grant is a reflection of 10 years of UK research in combination with the confidence and cooperation of one of Kentucky’s great corporations,” said CAER associate director Tom Robl, a principal investigator on the project. Jack Groppo of CAER is also a principal investigator.

Seated, from left: CAER Director, Ari Geertsema; U.S. Dept. of Energy Assistant Secretary for Fossil Fuels, Mike Smith
Standing, from left: Jack Groppo (CAER); Kenneth Tapp (LG & E); Tom Robl (CAER); Donald Miller (LG & E)
As part of the University of Kentucky, one of CAER’s responsibilities is in educational outreach. Below are some examples of outstanding students, whose time here has been rewarded recently.

CAER participates in Fayette County’s Experience Based Career Education (EBCE) Program for high school students, in which students go out into the workforce to gain experience. Our most recent student, **Amanda Napier** wrote a note to her mentor, Aurora Rubel, stressing how important this experience was for her. She says, “This internship has been very worthwhile and meaningful, and I have learned so much. It has also greatly furthered my interest in science and will help me in my college decisions. Before I came I wasn’t heavily considering the science field, but because of the opportunity I had in working with you and the CAER, it is now a choice at the top of my list.”

Paul Laurence Dunbar High School student, **Clair Anderson**, presented a paper at the recent American Coal Ash Association meeting in St. Petersburg, FL. The paper entitled, “Mercury Distribution on CCPs as a Function of Particle Size and Type” was very well received. Clair has worked at the CAER since February, 2002. Students at this math/science magnet high school choose a research project and work with an organization to gain hands-on experience with science outside the classroom.

**Sarah Mardon**, an undergraduate in UK’s Dept. of Geology and a CAER student worker, under the mentoring of Jim Hower, was selected to present a poster at the state capital in Frankfort on February 6th. The poster was titled “Impact of coal properties on coal combustion by-product quality: Examples from a Kentucky power plant.” The event was hosted by Kentucky’s eight public universities to ensure that members of Kentucky’s House and Senate, as well as the Governor, understand the importance of scholarly research to academic programs. Having students talk to their representatives about their projects is an extremely effective means of helping legislators understand the importance of these educational opportunities.
Last spring at the annual Coal Prep conference in Lexington, Kentucky, the Coal Preparation Society of America (CPSA) was introduced at the keynote session. The principal objective of CPSA is the education of people in the coal-electric utility industry and the public at-large about the issues associated with coal preparation. These issues encompass not only process technology, but also the environment and economics.

There is an on-going debate in the world concerning the combustion of fossil fuels and global warming. Key drivers in the debate are the complex mathematical computer models that purport to predict the impact of fossil emissions on the weather in the future. Trying to model the weather, given the vast number of interactions and assumptions involved, is a daunting task to those of us who construct technical models for a living. Frankly, when the models can accurately predict what's going to happen 100 hours from now, I'll feel more comfortable with what they predict for 100 years from now. Unfortunately, the debate has more to do with theology than technology. People on both sides are locked into defensive positions instead of analyzing the big picture and coming-up with solutions that can work.

The American media loves a disaster. Disaster sells advertising for beer, and cereal because disaster gets the juices flowing. Scientists who predict gloom and doom from global warming and focus on disastrous implications get the funding. A theory that a modest rise in temperature melts Antarctica and inundates all of the world's coastal areas gets airtime. An equally valid theory that a modest rise in temperature extends the growing season and causes increased cloud formation and rainfall - thereby increasing world crop yields and reducing famine, gets a yawn.

The global warming debate produces lots of heat, but not much light. This is where CPSA comes in. We want to shed some light on the debate.

Let's assume for the moment that coal-fired plants in North America make a significant contribution to global warming, and that the resultant warming would be detrimental to the environment (neither assumption can be proven, but let's make the assumptions anyway). What can we do?

My neighbor, a very bright woman and a degreed engineer, speculated a couple of years ago that maybe the energy companies were holding back technologies like wind and solar, despite the fact that those technologies were economical. The nefarious end was to protect their fossil fuel fiefdoms. At the time, my response was that if the technology was economically viable, the Japanese, or Swiss, or someone else would be implementing it on a large scale. Countries like Japan and Switzerland have lots of smart people, technological capability, and little to no indigenous fossil fuel resources. What reason would they have to hold back the technology? In a word - none.

Recently, I talked to a colleague working on a solar energy project. He told me the costs of solar energy would be $120 per MWh, versus less than $20/MWh for power from their existing coal-fired units. The reason we don't have more solar and wind power is that these sources can't compete economically with coal-fired power.

So, where does this leave us? We shut down all of the low-cost coal-fired plants. Many of those plants are converted to natural gas, and gas being an elastic commodity, the price of natural gas in North America soars. We also build plants to generate high-price electricity from wind and solar. Industry and service sectors sensitive to electricity prices move offshore to countries with lower prices. Our competitors are ecstatic. This was the idea behind Kyoto in the first place.

Where does that low-cost, offshore electricity come from? Coal-fired
plants. Only now those plants are in China, or Poland, or Mexico, or some other developing country given a pollution pass under the Kyoto Treaty. The net result is that instead of coal being burned in a modern, efficient plant in the US with state-of-the-art emissions controls, coal is burned in an inefficient plant with no emissions controls. As a consequence there will be an increase in global pollution, not to mention a higher death rate from increased coal production in third-world mines. So a government policy intended to make people’s lives better and improve the environment has the opposite effect.

This is not to say that we can’t implement measures to deal with environmental issues, economic issues, and coal utilization. The fact is that by using coal preparation to improve the quality of coal we burn in our power plants, we can reduce the emission of pollutants, reduce the cost of electricity, and increase the generating capacity of existing power plants.

Most of you already know that cleaning coal reduces sulfur emissions, but did you also know that cleaning removes rock in the coal and thereby improves efficiency and capacity? Did you know that cleaning typically removes over 50 percent of the mercury in coal? Our western coals typically contain 20 percent to 35 percent water. If we reduce the water content, we improve the efficiency of the boiler. If we improve the efficiency of the boiler, we reduce emissions across the board – including CO₂.

We have the technology to reduce the polluting and efficiency-robbing constituents in coal ahead of the boiler. We can improve upon that technology and give America and the rest of the world cleaner, cheaper power. To do this we must educate those in the utility industry, mining industry, regulators, and the general public about coal and coal cleaning.

At CPSA, this is our mission. We invite you to join us.

For more information on CPSA, contact Mr. Alderman at mass4systems@earthlink.net.