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Coal Use and Fly Ash Disposal in Israel

Henry A. Foner and Thomas L. Robl
UK Center for Applied Energy Research

BACKGROUND

Traditionally all electric power in Israel has been generated from heavy fuel oil. However, the oil crisis of the 1970's and the fall of the Shah of Iran in 1979 so disrupted the traditional supplies of fuel, that the Israeli government decided to diversify its sources of power. For this reason the Hadera power station, which was under construction at that time, was modified to be run on either coal or oil. The power station was commissioned in 1982 and from that time on, all new major generating capacity has been based on coal.

Figure 1 shows the location and type of electricity generating plants in Israel. All the power stations are on the coast mainly because the only convenient source of cooling water is the Mediterranean sea. Also, all fuel is imported and it is cheaper and more convenient not to have to move solid fuel inland. The coal used is of low sulfur content (<1%) and is imported from a number of countries as shown in Table 1. At Hadera a jetty was built to handle the coal, while the Ashkelon station is supplied by conveyer from a special coal handling facility built at the nearby port of Ashdod.

The population of Israel is increasing rapidly as the country is also becoming more industrialized. Figure 2(a) shows the exponentially increasing demand for electricity and Figure 2(b) illustrates the fuel imports for power production. Small scale use of coal is forbidden in Israel because of pollution concerns. Efforts to interest larger industrial concerns in the use of coal have been made but only with limited success; general industrial use is currently only about 30,000 tons per year.

From the beginning of coal imports, the question of what to do with the resulting ash has been under much discussion. Many possible solutions have been suggested, including such unusual ones as building islands off the coast to increase the amount of land available for building. What has in fact been done is shown in Table 2. However, the alternatives shown here are now either no longer practicable or available. The amount of fly ash that may be added to Portland cement is limited by the Israel Standard to 10%. Dumping at sea caused damage to some forms of sea life over a limited

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Figure 1. Electricity generating plants

COAL COMBUSTION BYPRODUCT HAULBACK TODAY

William E. Giles
Freeman United Coal Mining Co.

Coal mining companies have been utilizing coal combustion byproduct (CCB) backhaul operations as a marketing tool for several years. A backhaul operation allows coal to be shipped to the customer and CCBs to be returned to the coal shipper. The CCBs may be returned to the mine where the coal was produced or to a central location where the CCBs are distributed to mines, mined land-reclamation-projects or disposal areas. Backhaul operations may give a coal mining company a competitive edge in an adverse marketplace. The customers that are interested in backhaul operations generally do not have longterm site-disposal facilities or have a limited volume in existing facilities. The reason for backhaul contracts is entirely economical. The cost of returning the CCBs to the mine that produced the coal or to another mine operated facility is normally less than the cost of building an on-site disposal facility or hauling the CCBs to a commercial landfill. CCBs are large-volume low-value materials. Although they may possibly be reused, the cost may well be higher than the cost of using new materials. Some states have recognized that CCBs generally do not pose any threat to the environment and have provided incentives to use the CCBs as construction materials and in other innovative ways. Some alkaline CCBs are used for sewage sludge stabilization. Backhauled CCBs may be beneficially used for reclamation, but the volume of CCBs often exceed the demand and the remaining CCBs are commonly landfilled.

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Coal Use, (continued)

area and has been forbidden by the Ministry of the Environment; also there is no more room around the power stations to build embankments. The Ministry of the Environment has also been reluctant to approve the use of ash as landfill (or, for that matter, to dump it in embankments near the power stations) because of the possibility of contaminating the shallow drinking water aquifers with toxic trace elements leached out of the ash.

By the year 2001, Israel will produce about 1,300,000 tons of ash annually and of this, only about 600,000 tons can be used by the cement industry under the present regulations. The question is then, what to do with the rest? It is this question that we address in the remainder of this article.

FLY ASH

About 85 % of the ash produced in Israel is "fly ash," which is recovered from the power station chimneys (rather than from the boilers) and as this contains most of the trace elements, it is the major portion of the ash disposal problem. We studied two representative samples of Israel fly ash at the CAER this year. These samples, called South African (SA) and Colombian (CO) from their approximate source types, were prepared by the "Coal Ash Administration" set up in Israel to investigate problems of ash disposal.

The starting point of our study at CAER was the assumption that coal fly ash is a potentially valuable material and that it should not automatically be treated as a waste product that must be disposed of at considerable cost. Worldwide, there are numerous examples of economically beneficial fly ash utilization and the situation in Israel seems to us to be another promising case.

The type of fly ash available in Israel is classified by the ASTM as a class F material. Class F fly ashes are derived from relatively high grade bituminous or better grade coals and have low calcium contents. This type of fly ash is principally composed of small (10 mm or less) glassy aluminosilicate spheres. The latter are formed by the rapid cooling of the molten mineral matter in the pulverized coal used in the power station boilers. The principal property of these spheres is that they are pozzolanic, *i.e.* they react with free lime (which is present in hydrated Portland cement). A good quality pozzolan improves many of the important properties of concrete, particularly its durability and permeability. By tying up the free lime, the pozzolan reduces the susceptibility of the concrete to sulfate attack, carbonation and chlorination.

In order to market fly ash as a pozzolan, it should be of good quality and consistent in nature. Many countries have standards for this purpose and these are usually very similar to those adopted in the USA by the ASTM. In our study of these fly ashes we have determined the chemical mineralogical and technical properties of the two representative samples. In order to test the possibility of beneficiating the original materials we have also carried out the same tests on various sized fractions of the ash.

SOME TEST RESULTS

Table 3 shows the particle size distribution of the original samples and also the carbon content of the various size fractions. It can be seen that the larger sized fractions contain large proportions of carbon. Table 4 shows the carbon content of the fly ash after passing through the specified sieves. The carbon content of the ash is significantly reduced by removing the >100 mesh or >200 mesh material. With the gradual introduction of low-NO_x burners, the amount of residual carbon in the fly ash is expected to increase, so carbon removal will become a more important factor in ash beneficiation. Although carbon is undesirable in the ash (as it adsorbs air entraining agent), it can be used for fuel or as an industrial adsorbent when separated.

The principal technical test of the suitability of a fly ash for use as a pozzolan is the Strength Activity Index (SAI). This is an accelerated test which compares the compressive strengths of two cement/sand mortars; one made with an Ordinary Portland Cement (OPC) and the other made with same OPC but with 20 % of the cement substituted by fly ash. Table 5 shows the results obtained on the original Israel ash samples and on various size fractions obtained from them by careful dry sieving.

Both raw ash samples give SAI values greater than the minimum required by the ASTM standard (75 %), with increasing values as the coarse fraction is removed. The South African sample is particularly good. Table 6 lists a number of other chemical and technical parameters referred to in various ASTM standards and the results obtained in tests on the representative ash samples

Table 1. *Sources of Coal Imported into Israel in 1997*

Country	No. of Mines	%	Country	No. of Mines	%
South Africa	8	50-52	Australia	4-5	11
U.S.A.	3-4	15	Indonesia	1	5-7
Colombia	2-3	17			

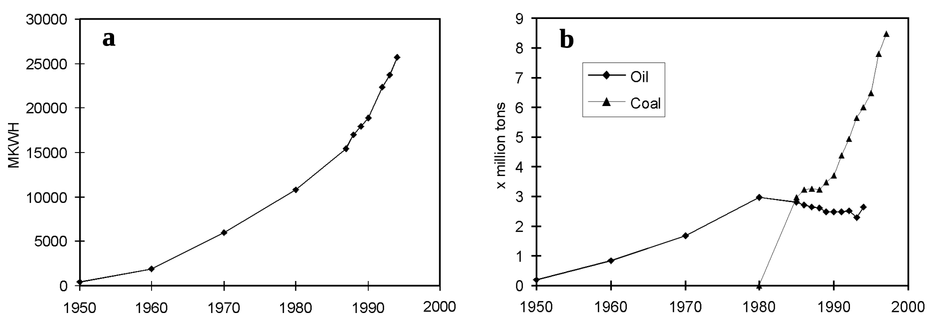


Figure 2. Electricity production and fuel uses from 1950 to recent years.

Table 2. *Amounts of ash produced, utilized and disposed of in Israel: Total and recent years (thousands of tons)*

	1993	1994	1995	1982-95
Total Production	640	650	735	6060
<u>*Utilization/disposal:*</u>				
Cement production	420	440	630	3910
Embankments	150	160	20	1120
Disposal at sea	70	50	85	1030

and their various size fractions. The maximum or minimum values allowed in the standards are also shown.

DISCUSSION

The test results show that the original samples are good quality Type F fly ashes. The SA ash is better than the CO. However, relatively simple separation processes (such as air or hydraulic classification) would produce a <200 mesh product which should be more marketable and would have the added advantage of supplying products which could easily be blended to give particular desirable properties. Some possible uses of fly ash which might be particularly suitable for Israel are listed in the next column. Although some of these uses simply replace existing materials with fly ash, others could be the basis of completely new industries. One or more of these uses might entirely solve the environmental and economic problems of ash disposal in Israel. This approach which utilizes the natural pozzolanic properties of the material seems preferable to more "exotic" approaches such as the extraction of aluminum or trace elements.

Table 3. *Size fractions of the ash components and the percentage of carbon in each*

Size		South African		Colombian	
Fraction	size ((m)	%	carbon %	%	carbon %
>100 mesh	>150	1.9	24.6	4.5	46.8
100-200	150-75	8.2	13.7	10.0	16.2
200-325	75-45	10.6	4.16	9.2	4.11
<325	<45	79.2	1.63	76.3	2.76

Table 4. *Carbon Content of Classified Ash Samples*

		South African	Colombian
Fraction	size	% carbon	% carbon
Whole sample		3.3-4.2*	6.2-7.1*
<100 mesh	< 150 micron	2.90	4.30
< 200 mesh	< 75 micron	1.93	2.91

**depending on the sample*

Table 5. *Compressive strengths (in psi) and SAI (in %) at 7, 34 and 56 days for various sieve size ash fractions.* ***Note****: ASTM requirement for SAI = 75% at 7 or 28 days*

Sample	7 day Comp. Str	7 days SAI %	34 day Comp. Str.	34 day SAI %	56 day Comp. Str.	56 day SAI %
Cement	4310	100	6220	100	6900	100
CO -10 mesh	3540	82	5340	86	6100	88
CO -100 mesh	3330	77	5440	88	6240	90
CO -200 mesh	3670	85	5800	93	6500	94
SA -10 mesh	3770	88	6020	97	6710	97
SA -100 mesh	4070	95	6170	99	7150	104
SA -200 mesh	4150	96	6500	105	7460	108

Possible Uses

- A pozzolan for cement in addition to the amounts already used. In large scale projects such as dams, ports, etc., the proportion of ash that can be used is considerably more than the approximately 20 % which is routinely added to OPC in the US. This has special importance in reference to the current "Peace Process" in the Middle East as many large scale construction projects are planned, especially in the Gaza area. The use of fly ash in these projects would represent a considerable money savings to all the parties involved. It should be noted that the Ashkelon power station is situated very close to the Gaza strip.
- As a replacement for the fine aggregate (sea sand or machine-ground sand) in concretes and mortars.
- As a raw material for light-weight aggregate production. Some commercial systems are available for this purpose.
- As a constituent of light-weight aerated concrete, especially for construction of insulating building blocks. These could replace many of the low-fines concrete blocks used presently.
- As a constituent of "flowable fill" for filling trenches, and surrounding insulation in building basements, shelters, foundations etc.
- Export of fly ash. The Middle East region is lacking in good quality pozzolans. Good quality fly ash can be sold for up to $20 / ton in many markets and for considerably more in the Red Sea States.

Dr. Henry Foner is with the Geological Survey of Israel in Jerusalem where he has served in a variety of tasks including Head of the Geochemistry Division. Dr. Foner was educated at the University of Leeds (U.K.). He was also a recent visiting scientist at the CAER.

Table 6. *Various Chemical and Technical Parameters based on ASTM Specifications (note: Fineness limit is for Portland Cement)*

Sample	Blaine Fineness (m^2/kg)	Water requirement (%)	Retained on wet 45 mm sieve	SiO_2 $+Al_2O_3$ $+Fe_2O_3$	SO_3 (%)	LOI (%)	Moisture (%)	Multiple Factor
ASTM	C150-89	C618-89	C618-89	C618-89	C618-89	C618-89	C618-89	C618-89
Limit	280 min.	105 max.	34 max.	70% min.		10 max.	3 max.	255 max.
CO	328	101	25.7	88.4%	0.4	6.8	0.20	175
CO <100	319	99	23.0					
CO <200	322	97	16.4					
SA	363	97	20.7	81.2%	0.5	4.0	0.23	83
SA <100	370	96	19					
SA <200	375	95	11.9					

Haulback, (continued)

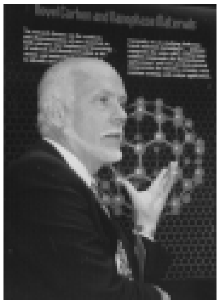
As backhaul operations gain popularity with coal customers, it is becoming necessary for the mine operator to deal with various types, quantities and properties of coal combustion byproducts. Coal-market conditions may dictate the amount of coal sales that will be used to offset the CCBs shipped back to the mine. Whether the CCBs are disposed of or used for beneficial operations has an effect on the handling methods. CCBs may compete with coal refuse for available space. Disposal areas at mine sites must be properly permitted and constructed. This process is time consuming and expensive. CCB volumes may be seasonal and it may be difficult to handle the traffic at peak times.

There can be wide variations in the physical and chemical characteristics of the CCBs produced at different sites. A coal mining company with a number of backhaul customers will have to be able to handle and dispose of the different types of CCBs. Their volume, characteristics, delivery means and schedules must be taken into account when planning the backhaul operation. The effects of one type of CCB on the others may require special handling. Before entering into a backhaul agreement, samples of the CCBs are analyzed for chemical constituents and leaching potential. When CCBs from different sources are handled at the same facility, composite samples are analyzed in the same manner. Once the CCBs reach the mine, the operator must determine the most cost-efficient way to handle the CCBs. Some CCBs have been used for mine reclamation, but the volume of CCBs received may be much larger than the amount needed for reclamation. Most CCBs contain some alkalinity. This makes them potentially useful in mine reclamation. In surface mines, the rock overlying the coal is removed to expose the coal for mining. After the coal has been mined, the CCBs may be placed against the exposed coal seam or on the mine floor to help control acid-water generation after the waste rock has been returned to the pit. At underground mines, CCBs may be mixed with coal processing refuse or placed over refuse for the same purpose. Even when reclamation is not the purpose, it is not uncommon for coal processing wastes and CCBs to be mixed or, at least, placed in the same disposal site. There is a possibility that some CCBs may be used for structural fill in CCB - mine refuse disposal site construction. Some CCBs have been injected into abandoned underground mine works to help support the mine roof and prevent subsidence, but this is expensive and not yet common.

Freeman United Coal Mining Company has been engaged in CCB backhaul operations since 1991. Since that time we have handled over two million tons of CCBs at several locations and we presently have about ten customers using haulback contracts. Not all of our mines are suitable for CCB disposal, so sometimes they are delivered to one mine and the coal is shipped from another nearby. Flexibility has been built into our operations to allow for changes that may occur during the term of the contract and for new contracts that may be secured. We have considered many different methods of handling and disposing of CCBs. We utilize CCBs constructively whenever possible, but still have a great deal left over. We understand that there are concerns over the longterm effect of CCBs on the environment and we constantly monitor for changes. Nonetheless, we believe that CCBs will be benign or beneficial in most applications.

This brings us to our need for organizations such as the Center for Applied Energy Research. It is important for us to cooperate with these institutions to study the uses and effects of CCBs. It is important that these institutions remain impartial and open to all possible consequences of proposed uses, good and bad. The study and characterization of CCBs has given us insight into their behavior and is useful in planning our operations. Observation of weathering of CCBs has given us information on their stability and ultimate fate in the environment. We need this kind of information for our own use, but it is also important that this information reach the regulatory agencies and the public. With the knowledge that we have gained from the research into CCBs, we can now make informed decisions as to their suitability for our purpose.

Bill Giles has been with Freeman United Coal Mining Company since 1976 and has worked with Coal Ash Handling And Disposal since 1990.



1997 Carbon Workshops

On 10 - 11th July, the CAER held two workshops on carbon materials at the Hyatt Regency Hotel in Lexington: a fourth workshop on Adsorbent Carbons and a second on closed -cage carbon molecules, entitled “The Science of Carbon Nanotubes.” The former was initiated by Frank Derbyshire and the latter by Peter Eklund, who formed a committee to develop the scientific program. The organization and arrangements were made by the staff of the CAER. The meetings were held in parallel, with some joint sessions.

As a deliberate policy, attendance at these meetings has been limited to promote discussion and interaction. This formula has been very successful. It is attractive to most of the attendees who can gain much more from a short, focused meeting than is often possible at large international conferences. The gathering in July was one of the most successful yet, not the least because we were honored by the presence of Nobel laureate Richard Smalley who gave a presentation on the “Future of Fullerenes.”

In providing this brief account, we would like to take another opportunity to recognize the speakers and session chairs, as well as other attendees, and to thank the various sponsors who made the meetings possible by providing financial support and, in many cases, sent their representatives.

Sponsors of workshop on the Science of Carbon Nanotubes

- Kentucky NSF/ EPSCoR
- UK Office of the Vice President for Research and Graduate Studies
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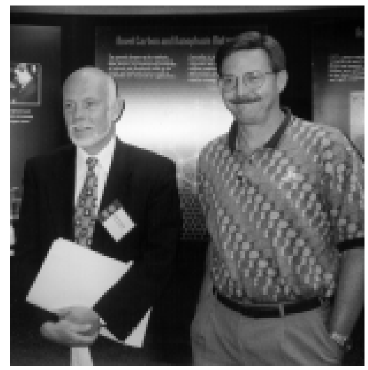

They’re Back!

The first issue of Energeia in 1997 contained a notice of CAER’s Drs. Apparao Rao and Peter Eklund publishing an article in **Science** Magazine. Now The two have coauthored an article entitled “Evidence for charge transfer in doped carbon nanotube bundles from Raman scattering,” in the July 17th issue of the prestigious journal NATURE. Other coauthors include: Shunji Bandow (Institute for Molecular Science), and A. Thess and Richard Smalley (Rice University).

The authors have shown in this article that both n-type and p-type chemical dopants can be used to increase the electrical and thermal conductivity of the carbon nanotube by a factor of 20 or greater; “ropes” or bundles of nanotubes were investigated and the dopant may reside in the triangular, interstitial channels (between nanotubes) in the bundle.

Congratulations to two of the CAER’s own!

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Center for Applied Energy Research
2540 Research Park Drive
University of Kentucky
Lexington, Kentucky 40511-8410

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