COAL COMBUSTION PRODUCTS

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The working definition for solid materials resulting from the combustion of coal has been evolving. Environmental regulators first used the term coal combustion wastes. Later, the term coal combustion byproducts gained popularity. Lately, coal combustion products (CCPs) has become a household term for those in the power industry, the ash marketers, and most users of these materials. The solids included in CCPs are fly ash, bottom ash, boiler slags, and flue gas desulfurization (FGD) material (synthetic gypsum). Fly ash is the fine fraction of the CCPs that is carried out of the boiler by the flue gases. Almost all fly ash is captured by dust collecting systems, such as electrostatic precipitators. Bottom ash is defined as the large ash particles that accumulate at the bottom of the boiler. Boiler slag is the molten inorganic material that is collected at the bottom of the boilers and discharged into a water-filled pit where it is quenched and removed as glassy particles resembling sand.

Electricity accounts for more than one-third of the primary energy used in the United States, and more than one-half of the Nation’s electricity is generated by burning coal. Coal burning, combined with pollution control technologies, generates large quantities of CCPs. During 2000, about 860 million metric tons (Mt) of coal was burned, and about 98 Mt of CCPs was generated by the electric utilities.

In addition to the ash, sulfur in flue gases emitted from fossil-fuel-burning electricity-generating plants is also a concern for the environment. The majority of electric power utilities, especially in the Eastern and Midwestern States, use high-sulfur bituminous coal. Increased use of high-sulfur coal has contributed to an acid rain problem in North America. To address this problem, the U.S. Congress passed the Clean Air Act Amendments of 1990 (CAAA ’90) (Public Law 101-549) with stringent restrictions on sulfur oxide emissions. The sulfur dioxide (SO_2) reduction provisions of the CAAA, which would be implemented in a two-phase plan to be completed by 2010, forced the electric utilities to find ways of reducing SO_2 emissions. A number of utilities have switched to alternative fuels, such as low-sulfur coal or fuel oil, as partial or temporary solutions to the problem. A significant number of electric utilities still using high-sulfur coal have installed FGD units.

FGD units remove SO_2 from flue gas but, in doing so, generate large quantities of synthetic gypsum (FGD material), which is a mixture of gypsum, calcium sulfite ($CaSO_3$), fly ash, and unreacted lime or limestone. A number of powerplants convert the $CaSO_3$ to calcium sulfate by forced oxidation and take appropriate measures to reduce the other impurities in the FGD material to produce synthetic gypsum that exceeds the specification for wallboard manufacture. Wallboard plants, recently constructed adjacent to such electric utilities, use the FGD gypsum from those electric utilities. The FGD material adds to the accumulation of already high levels of CCPs. About 23 Mt of FGD material was produced in 2000, and about 4.5 Mt (20%) was used mostly for wallboard manufacture.

FGD issues affect, directly or indirectly, coal, gypsum, lime, limestone, and soda ash producers. Increased commercial use of FGD products represents an economic opportunity for high-sulfur coal producers and the sorbent industry (especially lime and limestone). Today, synthetic gypsum competes directly with natural mined gypsum as raw material for wallboard manufacture.

The value of CCPs is well established by research and commercial practice in the United States and abroad. As engineering materials, these products can add value while helping conserve the Nation’s natural resources.

Fly ash represents a major component (58%) of CCPs produced, followed by FGD material (24%), bottom ash

Coal Combustion Products in the 20th Century

The history of coal combustion products (CCPs) began 2000 years ago with the use of fly ash by the Romans in the construction of aqueducts and coliseums. The first research on fly ash was reported in the Proceedings of the American Concrete Institute in 1937, which introduced the term “fly ash” to the literature. Chicago Fly Ash Co., formed in 1946, was the first to market fly ash as a construction material for manufacturing concrete pipe. The U.S. Bureau of Reclamation used fly ash on a large scale in the construction of the Hungry Horse Dam in Montana in 1949. Six other dams were constructed during the 1950s using fly ash concrete. Initial markets for fly ash were as a portland cement extender and as an enhancer of the qualities of concrete to meet new postwar requirements.

In 2000, almost 1 billion metric tons of coal was burned, which generated 120 million metric tons of CCPs. Electric utilities alone burned over 860 million tons of coal and generated over 98 million tons of CCPs, almost 30 million tons of which was used in a number of areas, primarily in cement and concrete (11.7 million tons), structural fills (4.9 million tons), waste stabilization (2.0 million tons), road base/subbase (1.2 million metric tons), and mining (1.1 million tons) applications. Innovative high-volume applications are being developed. In 2000, CCPs were used as a raw material in numerous products ranging from wallboard to bowling balls.

(15.5%), and boiler slag (2.5%). Among the major CCP components, fly ash and FGD materials boast the highest use rate at about 32% of the amount produced.

Legislation and Government Programs

The Resource Conservation and Recovery Act (RCRA), enacted in 1976, has been the primary statute governing the management and use of CCPs. CCPs have been the subject of investigation by the U.S. Environmental Protection Agency (EPA), which published its regulatory determination on wastes from the combustion of fossil fuels in May (U.S. Environmental Protection Agency, 2000). The agency concluded that CCPs do not pose sufficient danger to the environment to warrant regulations under section 3001(b)(3)(C) of subtitle C of the RCRA. However, the EPA also determined that national regulations under subtitle D of the RCRA are warranted for CCPs when they are disposed of in landfills or surface impoundments. Furthermore, possible modifications to existing regulations established under the authority of the Surface Mining Control and Reclamation Act are warranted when they are used to fill surface or underground mines. A detailed review of Government regulations was made in an earlier publication (Kalyoncu, 2000).

The EPA, however, remains particularly critical of State programs and is concerned that Federal Government oversight is needed to ensure that minefilling is done appropriately to protect human health and the environment, particularly since minefilling is a recent but rapidly expanding use of coal combustion wastes (U.S. Environmental Protection Agency, 2000, p. 32231).

Production

Table 1 summarizes the historical production and use of CCPs for the years 1996 through 2000. A small, steady increase in CCP production rates through 2000 is apparent. In 1999, it was predicted that fly ash, bottom ash, and boiler slag production could be expected to remain flat in the near future, as no significant increase in the use of coal was planned for electric power generation. An unexpected jump in petroleum prices, however, may well change the Nation's energy equation in favor of increased coal use. An increase in ash generation can be expected with increased coal burning. The commencement of phase two of the CAAA in January 2000 is expected to contribute to a significant increase in synthetic gypsum generation in the years ahead. The energy policies of the new administration, which call for increased use of fossil fuels, especially use of coal in electric power generation, gives an additional reason to anticipate increases in the generation of CCPs.

Tables 2 through 4 list the domestic production and consumption data for 2000. Table 2 lists the total quantities of CCPs (dry and ponded), whereas tables 3 and 4 summarize the dry and ponded CCP data, respectively.

Graphic representations of CCP data are shown in figures 2 through 9. Figures 2 and 3 show historical CCP production and use data, respectively. Total CCPs production and use data for 2000 are presented in figure 4. Figure 5 depicts production by CCP type and region. Figures 6 through 9 show leading uses for fly ash, bottom ash, boiler slag, and FGD material, respectively.

Consumption

The components of CCPs have different uses because they have distinct chemical and physical properties; each one is suitable for a particular application. CCPs are used in cement and concrete, mine backfill, agriculture, blasting grit, and roofing applications. Other current uses include waste stabilization, road base/subbase, and wallboard production (synthetic gypsum). Potential FGD gypsum uses also include applications in subsidence and acid mine drainage control and as fillers and extenders.

Total CCP use in 2000 decreased to 28.59 Mt from 30.00 Mt in 1999, a 4.7% decrease. Fly ash, bottom ash, and boiler slag all showed slight decreases in use, whereas FGD material recorded an 8.7% increase over the 1999 figure (table 1).

Domestic CCP consumption data from 1996 to 2000 are summarized in figure 3. Figures 6 through 9 summarize the use data for individual CCP types. Among the CCPs, fly ash was used in the largest quantities and found the widest range of applications, with about 60% of annual consumption used in various structural applications. Use in cement and concrete production tops the list of leading fly ash applications with more than 50%, followed by structural fills and waste stabilization (figure 6).

Structural fill and road base/subbase applications are major bottom ash uses. About 65% of bottom ash is used in road base/subbase, structural fill, and snow and ice control (figure 7). Minor uses include concrete, mining applications, and cement clinker raw feed.

Bottom ash can also be used as fine aggregate in asphalt paving mixtures. Some bottom ash is sufficiently well graded that pavements containing bottom ash alone can meet gradation requirements. Bottom ash containing pyrites or porous particles is not suitable for use in hot mix asphalt mixtures, where strict gradation requirements exist. It is used more commonly in cold-mix emulsified asphalt mixtures, where gradation requirements and durability are not critical as in hot mix surface mixtures.

Owing to its considerable abrasive properties, boiler slag is used almost exclusively in the manufacture of blasting grit. Use as roofing granules is also a significant market area. Blasting grit and roofing granules make up almost 90% of boiler slag applications (figure 8).

Boiler slag can also be used as fine aggregate, especially in hot mix asphalt owing to its superior hardness, affinity for asphalt, and its dust-free surface, which aids in asphalt adhesion and resistance to stripping. Since boiler slag exhibits a uniform particle size, it is commonly blended with other aggregates for use in asphalt mixtures.

Wallboard manufacture (more than two-thirds of the total), concrete, mining applications, and structural fill account for the bulk of FGD product uses (figure 9). Structural fill and concrete account for a majority of other uses of FGD material. Agricultural uses account for only 2.3% of total FGD material use. However, potential FGD material use in agriculture exceeds even its use in wallboard manufacture. This potential, however, needs to be realized through demonstration studies.

The 1999 annual survey of CCPs elaborated on the unprecedented demand for wallboard experienced across the United States (Kalyoncu, 2001). In an attempt to meet the increased demand, the wallboard industry moved aggressively to increase the manufacturing capacity through new plant construction and succeeded in doing so. With the signs of recent downturn in the economy, however, demand for wallboard will not keep its current levels. U.S. Gypsum Co. closed several plants in Plaster City, PA; Gypsum, OH; and in Plasterco, VA. Georgia Pacific Corp. closed two of its Grand Rapids, MI, wallboard plants. Closures of old and openings of new plants by the industry resulted in net increase in wallboard production capacity, but owing to decline in demand for wallboard, the existing plants were operating below their production capacity (Olson, 2001). The plant closures are not expected to affect synthetic gypsum use by the wallboard industry, because most of the facilities using synthetic gypsum are recently built modern plants. Companies are closing old, antiquated plants that used natural gypsum and are more likely to close similar old plants designed to use natural gypsum as raw material. This will undoubtedly affect the natural gypsum industry.

World Review

Efforts were made to compile world production and consumption data for the year 2000. However, only 1999 data were provided by the respondents. Data were obtained from major European and Asian countries, including India, the Republic of Korea, China, and Russia. Table 5 summarizes partial world CCP statistics. In the table, data from 13 European Union countries are combined under the European Coal Combustion Products Association (ECOBA). ECOBA member countries are Belgium, France, Germany, Greece, Ireland, the Netherlands, Poland, Portugal, Spain, and the United Kingdom. ECOBA members account for over 90% of CCP production in Europe.

In 1999, the ECOBA profitably used 56% (31 Mt) of the 55.5 Mt of CCPs that its member countries generated compared with about 30% use in the United States. Over 18 Mt of the 37 Mt of fly ash produced was used (48% use rate). A slightly smaller fraction (44%) of bottom ash, 100% of boiler slag, and 87% of synthetic gypsum produced found beneficial uses (table 5). Raw material shortages and favorable state regulations account for the higher use rates of CCPs in Europe. As in the United States, ECOBA members used CCPs in a number of applications, with concrete leading the way at 37%, followed by portland cement manufacture with 31% and road construction with 21%; other uses made up the remainder (11%). Among the individual countries contacted, Canada, India, Israel, Japan, and South Africa reported partial CCP production and use data. Canada used about 1.9 Mt (27%) of 7 Mt of CCPs produced, whereas coal-burning electric utilities in India generated about 90 Mt of CCPs in 1999, of which about 13% (11.7 Mt) was used. The remainder was disposed of in wet ponds. In Japan, 1999 figures were 9.1 Mt and 7.65 Mt for production and use, respectively. These figures translate into an 84% use rate for Japan. The high disposal cost of CCPs in Japan ($100.00 per metric ton) make alternative uses economically viable (Mark Early, Barlow Junker Pty Ltd., oral commun., 2001).

Large volume CCP use in India, China, and the Republic of Korea is an environmental and economic necessity owing to the planned increase in coal-fired powerplants to meet future electricity needs and the high ash contents of coal burned. Current burning of coal, containing 40% to 45% mineral matter, generates 90 million metric tons per year (Mt/yr) of CCPs in India, most of which is disposed of in wet ponds in the vicinity of the plants. The situation in the Republic of Korea is even more serious owing to the fact that the Republic of Korea burns more coal for electricity production than any other country in the world. Coal in the Republic of Korea also contains high fractions of mineral matter, which results in the generation of CCP quantities four times that of the United States (table 5) (Ji-Young Ryu, Korea Electric Power Corporation, oral commun., 2001).

Current Research and Technology

Research and development activities have focused on improving FGD processes and finding new applications for CCPs, especially the FGD product. Japanese and West European researchers have led much of the activity in the development of new FGD technologies. Electric utilities in these countries have no room for the disposal of the products from the current FGD processes and are forced to find better solutions to flue gas emission problems. Research efforts emphasize the development of technology that requires less space for installation and yields smaller quantities of products than the well established methods using lime or limestone as sorbents.

Research and development efforts in FGD have been directed, for the most part, toward either decreasing the quantities of the reaction products or increasing their economic value to upgrade them from waste products to resources.

Consol Energy Corp. successfully manufactured aggregates from CCPs using a pelletization process it developed (Aggregates Manager, 2000). Fly ash and synthetic gypsum are combined by disk pelletization with moderate-temperature curing to form aggregates. If commercialized, such manufactured aggregates may eventually play an important role in the 2-billion-ton-per-year aggregates market.

In order to reduce nitrogen oxides emissions to meet the requirements of the CAAA's restrictions on nitrogen oxide (NO_x) emissions, many electric utilities installed no-NO_x burners. No-NO_x burners, however, lead to a significant increase in the unburned carbon content of fly ash, in certain cases exceeding 10%. High carbon content renders fly ash unsuitable for cement and concrete applications, which account for the bulk of fly ash use. Excess unburned carbon in concrete-containing fly ash cement reduces the freeze-thaw resistence of concrete by capturing the air entraining agents that are used to modify the microstructure by introducing controlled porosity.

Researchers at Pennsylvania State University have developed a method to economically separate unburned coal from fly ash (Skillings Mining Review, 1999). It appears that the unburned carbon separated from the fly ash is suitable for manufacturing activated carbon, which is used in water treatment and gas purification processes. These carbon products have a significant market with 350,000 metric tons per year sold. The unburned carbon, separated from fly ash, does not need cleaning or grinding, nor does it need heating to remove volatiles. While anthracite, which is currently used as the precursor in the manufacture of activated carbon, sells for about $50.00 per metric ton, the unburned-carbon in fly ash can be separated at $10 to $15 per metric ton, and the fly ash can be sold to concrete or cement producers.

Reports of research and development results during the past two decades indicate that an increase in the development of uses for CCPs will happen in small steps. At the 14th International Symposium on Management and Use of Coal Combustion Products, held in San Antonio, TX, in January 2001, researchers from industry, academia, and Federal and State Governments made presentations that covered a range of topics from characterization to applications of CCPs in landfills, agriculture, mine backfilling, acid mine abatement, manufacture of building blocks, and recovery of high-value rare-earth metals. The proceedings of the 14th symposium contain 82 papers, presented in 13 sessions (American Coal Ash Association, 2001).

As construction materials, CCPs add to and enhance the chemical durability while reducing costs. In agricultural applications, gypsum-rich products provide sulfur needed by plants. In waste stabilization, pozzolanic properties of these products can immobilize nuclear and toxic compounds and allow the disposal of such compounds in a safe manner. Substantial benefits to the society will include conservation of land and natural resources and reduction in CO_2 emissions.

There are a number of technical, economic, institutional, and legal barriers to the use of large quantities of CCPs. Technical and economic barriers are not mutually exclusive, in that technological advancements usually result in economic feasibility. Principal technical barriers include issues related to CCP production, specifications and standards, materials characterization, product demonstration and commercialization, and user-related factors.

Economic barriers to increased CCP use can be key among all factors affecting byproduct use. With proper economic incentives other barriers to increased use of CCPs can be overcome. For coal-burning electric utilities, the revenues from the sale of CCPs is often insignificant. The high cost of transporting the low unit-value CCPs and competition from locally available natural materials pose two of the most important economic barriers.

Among the institutional and legal barriers are the lack of knowledge of potential ash uses, the sporadic data on environmental and health effects, the compositional inconsistencies in the products, belief that other raw materials are readily available, the lack of State guidelines, and the viewpoint of the industry that EPA regulations and procurement guidelines are too complicated and rigid rather than being general guidelines for use.

A subcommittee of the American Society for Testing and Materials Committee E-50 on Environmental Assessment, on which the U.S. Geological Survey (USGS) is represented, was recently formed to address the question of standards and definitions of coal and CCP-related terms. The latest draft of the definitions document was evaluated by subcommittee members, and recommendations were submitted to the committee for action in 2001. This draft calls for the change of CCPs to coal combustion byproducts (CCBs), to iterate the ideal definition of a product, which is the principal reason for a process. It is argued that coal is burned to produce energy, not ash. Therefore, energy is the product of coal burning process; anything else is a byproduct.

The perception of potential harm to the environment leads to government policies that translate into rigid barriers to the use of CCPs. The recent decision by the EPA to list CCPs under subsection D of the RCRA, which classifies CCPs as potentially hazardous in mine reclamation and backfill applications, is a formidable barrier to the use of CCPs in mine applications. Researchers and marketing professionals have been making efforts to remove such barriers to the use of these materials.

Concerned industry and government representatives, scientists, and engineers have formed a number of national and international organizations to address the removal of barriers to use of CCPs. Some of the most prominent are the American Coal Ash Association (ACAA), the recently formed Coal Ash Resources Research Consortium (CARRC), the Center for Applied Energy Research (CAER), the Coal Combustion Byproducts Recycling Consortium (CBRC), the Coal Combustion Byproduct Information Network Steering Committee (CCBINSC), and a number of State organizations.

The ACAA, founded in 1968 by the coal-burning electric utilities and based in Alexandria, VA, has as its mission the advancement of the management and use of CCPs in ways that are technically sound, economically feasible, and environmentally safe. It serves producers and marketers of CCPs, coal producers, allied trade groups, consultants, and academic institutions. Since its establishment, the ACAA has helped shape the technical, educational, government relations, communications, and marketing efforts funded primarily by membership dues and income from educational programs and sales.

The CARRC, housed at the University of North Dakota Energy and Environmental Research Center, is an international organization of industry and government representatives and scientists working together to advance CCP use. The CARRC works to solve CCP-related problems and promote environmentally safe and technically sound use of CCPs. Over the years, the CARRC has contributed to the generation of scientific and engineering information on CCPs, the development of characterization methods, and demonstration of new CCP uses (University of North Dakota Energy and Environmental Research Center, [undated], What's CARRC?, accessed October 23, 2001, at URL http://www.undeerc.org/carrc/html/Whatscarrc.html).

The CBRC is a program of the National Mine and Land Reclamation Center, located at West Virginia University, in cooperation with the U.S. Department of Energy Technology Laboratory. The objective of the CBRC is to develop technologies for coal-burning utilities to solve problems related to production and use of CCPs. The CBRC has thus far sponsored two major CCP use demonstration projects and has published a request for proposals for a third project (Combustion Byproducts Recycling Consortium, [undated], Home page, accessed October 23, 2001, at URL http://cbrc.nrcce.wvu.edu/cbrchome.htm).

The CCBINSC, established in 1997, is a voluntary planning group made up of representatives from a number of Federal and State Government agencies, including the USGS, and research organizations to compile and disseminate the information available through a comprehensive web site. Since its establishment, the committee organizes and conducts a CCB forum every other year. An extensive source of technical inventories, current research activities, and governmental and legal developments on CCP issues is available on the U.S. Department of the Interior's Office of Surface Mining web site (CCB Information Network, [undated], Steering Committee, accessed October 23, 2001, at URL http://www.mcrcc.osmre.gov/ccb/Steering.htm).

A number of major symposia and conferences are held annually or every other year on the use and management of CCPs. Among such significant periodically held events are the International Ash Utilization Symposium, sponsored and run by the University of Kentucky; the ACAA's International Symposium on Management and Use of CCPs, held on odd-number years; the CCB's forum, sponsored and held by the CCBINSC on even-number years; and the annual International Pittsburgh Coal Conference, organized and run by the University of Pittsburgh.

Outlook

Two principal factors that will affect the size of the coal market and, therefore, quantities of CCPs generated are market deregulation and emissions regulations. Market deregulation will encourage electric utilities to search for the lowest cost fuel, and that will most probably be coal. On the other hand, there is the need to comply with phase two of the CAAA. Phase two of the CAAA, implemented in January 2000, capped powerplant SO_2 emissions nationally at 7.72 Mt/yr. As of January 2000, there were about 10 Mt of SO_2 allowances available for sale to noncompliant plants. The allowances were accrued during phase one of the CAAA. Quick disappearance of these allowances will force utilities to switch to clean fuels or to retrofit power plants with FGD units.

Increases in the production of fly ash and bottom ash will be proportional to the increase in coal use for electric power production. However, there may be a significant rise in the FGD material owing to the implementation of phase two of the CAAA. Only 10% of the utilities were affected by the first phase of the implementation of the law. A noticeable increase in the quantities of FGD material produced will become apparent in the coming years. Currently, power generation systems with more than 10,000-megawatt (MW) capacity support FGD units, and limestone units with more than 6,000-MW capacity and lime units with nearly 4,000-MW capacity are under construction. Moreover, the construction of limestone systems with 7,000-MW capacity and lime systems with 6,000-MW capacity are in the planning stage. When operational, these systems are expected to more than triple the quantity of FGD material to about 75 Mt/yr from the current level of 24 Mt/yr. With continued installation of FGD units, FGD material production could double the amount of CCPs currently being generated. Combined with the potential effect of future EPA rulemaking, this presents a formidable challenge to electric utilities and CCP-user industries.

To answer the challenge, utilities will continue to look for pollution-prevention technologies that will yield lesser quantities but purer and higher value FGD material. An example of such a trend is seen at Basin Electric Cooperative's Dakota Gasification plant in Beulah, ND, where a wet-ammonia-based FGD unit is used to remove SO_2 in the combustion of otherwise nonsaleable fuels derived from gasification of lignite. The resulting ammonium sulfate is sold and used as a sulfur blending stock in fertilizer production (William Ellison, Ellison Consultants, oral commun., 1999).

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GENERAL SOURCES OF INFORMATION

U.S. Geological Survey Publications

Gypsum. Ch. in Mineral Commodity Summaries, annual.
Gypsum. Mineral Industry Surveys, annual and monthly.

TABLE 1
HISTORIC COAL COMBUSTION PRODUCT PRODUCTION AND USE

(Thousand metric tons)

	1996	1997	1998	1999	2000
Fly ash:					
Production	53,900	54,700	57,200	56,900	57,100
Use	14,700	17,500	19,200	18,900	17,600
Percent use	27.50	32.10	33.60	33.20	30.90
Bottom ash:					
Production	14,600	15,400	15,200	15,300	15,400
Use	4,430	4,600	4,760	4,930	4,460
Percent use	30.40	30.20	31.30	32.10	29.00
Boiler slag:					
Production	2,360	2,490	2,710	2,620	2,430
Use	2,170	2,340	2,170	2,150	2,120
Percent use	92.30	94.10	80.10	81.80	87.00
FGD material: 1/					
Production	21,700	22,800	22,700	22,300	23,300
Use	1,500	1,980	2,260	4,030	4,380
Percent use	6.96	8.67	10.00	18.10	18.80
Total CCPs:					
Production	92,400	95,400	97,800	97,100	98,200
Use	22,800	26,500	28,400	30,000	28,600
Percent use	24.90	27.80	29.00	30.80	29.10

1/ FGD: flue gas desulfurization.

Source: American Coal Ash Association.

TABLE 2
TOTAL COAL COMBUSTION PRODUCT PRODUCTION AND USE, 2000 1/

(Thousand metric tons)

	Fly ash	Bottom ash	Boiler slag	FGD 2/ material	Total CCPs
Production	57,100	15,400	2,440	23,300	98,200
Use:					
Agriculture	13	4	--	69	86
Blasting grit-roofing granules	--	133	1,900	--	2,030
Cement clinker raw feed	1,030	158	--	--	2,290
Concrete-grout	9,600	381	(3/)	318	10,300
Flowable fill	632	10	16	30	688
Mineral filler	108	93	11	(3/)	212
Mining applications	1,050	333	--	166	1,550
Roadbase-subbase	1,100	759	(3/)	85	1,940
Snow and ice control	3	755	53	--	811
Soil modification	102	25	--	--	127
Structural fills	2,370	1,230	32	496	4,130
Wallboard	--	--	--	3,020	3,020
Waste stabilization-solidification	1,800	32	--	19	1,850
Other	413	571	89	173	1,250
Total	18,200	4,480	2,110	4,380	24,800
Individual use percentage	31.90	29.20	86.50	18.80	29.10
Cumulative use percentage	31.90	31.30	33.10	29.70	NA

NA Not available. -- Zero.
1/ Total CCPs include categories I and II, dry and ponded respectively.
2/ FGD: flue gas desulfurization.
3/ Less than 1/2 unit.

Source: American Coal Ash Association.

TABLE 3
DRY COAL COMBUSTION PRODUCT PRODUCTION AND USE, 2000

(Thousand metric tons)

	Fly ash	Bottom ash	Boiler slag	FGD material 1/	Total CCPs
Production	42,600	9,420	756	18,400	71,200
Use:					
Agriculture	13	4	--	66	83
Blasting grit-roofing granules	--	102	610	--	712
Cement clinker raw feed	818	142	--	--	960
Concrete-grout	9,240	276	--	317	9,830
Flowable fill	274	10	--	1	285
Mineral filler	106	51	11	(2/)	168
Mining applications	682	258	--	164	1,100
Roadbase-subbase	1,070	508	--	85	1,660
Snow and ice control	3	489	12	--	504
Soil modification	71	22	--	--	93
Structural fills	2,320	483	32	496	3,330
Wallboard	--	--	--	2,160	2,160
Waste stabilization-solidification	1,800	27	--	19	1,850
Other	68	336	28	170	602
Total	16,500	2,710	693	3,480	19,900
Individual use percentage	38.60	28.70	91.70	19.00	NA
Cumulative use percentage	38.60	36.80	37.60	32.80	NA

NA Not available. -- Zero.
1/ FGD: flue gas desulfurization.
2/ Less than 1/2 unit.

Source: American Coal Ash Association.

TABLE 4
PONDED COAL COMBUSTION PRODUCT PRODUCTION AND USE, 2000

(Thousand metric tons)

	Fly ash	Bottom ash	Boiler slag	FGD material 1/	Total CCPs
Production	14,500	5,920	1,680	4,900	22,100
Use:					
Agriculture	--	--	--	3	3
Blasting grit/roofing granules	--	31	1,290	--	1,320
Cement clinker raw feed	211	15	--	--	226
Concrete-grout	362	105	(2/)	1	468
Flowable fill	358	(2/)	16	29	403
Mineral filler	2	42	--	--	44
Mining applications	363	75	--	2	440
Roadbase-subbase	30	251	(2/)	--	281
Snow and ice control	--	266	41	--	307
Soil modification	30	4	--	--	34
Structural fills	51	743	(2/)	--	794
Wallboard	--	--	--	857	857
Waste stabilization-solidification	--	5	--	--	5
Other	346	235	61	3	645
Total	1,750	1,770	1,410	895	4,940
Individual use percentage	12.10	29.90	84.10	18.30	NA
Cumulative use percentage	12.10	17.30	22.40	21.60	NA

NA Not available. -- Zero.
1/ FGD: flue gas desulfurization.
2/ Less than 1/2 unit.

Source: American Coal Ash Association.

TABLE 5
WORLD COAL COMBUSTION PRODUCTS PRODUCTION AND USE, 2000

(Thousand metric tons)

Country	Fly ash	Bottom ash	Boiler slag	FBC ashes	Other	SDA product	FGD gypsum	Total	Percent use
European Coal Combustion Products Association:									
Production	37.14	5.62	2.42	0.99	0.24	0.52	7.57	54.50	XX
Use:									
Cement raw material	3.74	0.05	--	--	--	--	--	3.79	6.8
Blended cement	1.93	--	--	0.01	--	--	--	1.94	3.5
Concrete addition	5.44	0.02	0.16	0.03	--	--	--	5.65	10.2
Aerated concrete blocks	0.67	0.07	--	--	--	--	--	0.74	1.3
Nonaerated concrete blocks	0.59	1.23	--	--	--	--	--	1.83	3.3
Lightweight aggregate	0.24	0.08	--	--	--	0.01	--	0.32	0.6
Bricks and ceramics	0.07	--	--	--	--	--	--	0.07	0.1
Grouting	0.52	--	0.16	--	--	--	--	0.68	1.2
Asphalt filler	0.19	--	--	0.05	--	--	--	0.24	0.4
Subgrade stabilization	0.33	0.03	--	--	--	--	--	0.36	0.7
Pavement base course	0.21	0.33	1.25	--	--	--	--	1.78	3.2
General engineering fill	1.30	0.37	--	--	--	0.03	--	1.70	3.1
Structural fill	1.39	0.18	--	--	--	--	--	1.57	2.8
Soil amendment	(1/)	--	--	--	--	0.08	--	0.09	0.2
Infill	1.38	--	--	0.36	--	0.32	--	2.05	3.7
Blasting grit	--	--	0.73	--	--	--	--	0.73	1.3
Plant nutrition	--	--	0.04	--	--	0.04	--	0.07	0.1
Set retarder for cement	--	--	--	--	--	--	0.47	0.47	0.8
Projection plaster	--	--	--	--	--	--	0.62	0.62	1.1
Plaster boards	--	--	--	--	--	--	4.04	4.04	7.3
Gypsum blocks	--	--	--	--	--	--	0.24	0.24	0.4
Self leveling floor screeds	--	--	--	--	--	--	1.25	1.25	2.3
Other uses	0.20	0.13	0.09	(1/)	0.24	--	--	0.65	1.2
Total	18.17	2.50	2.42	0.45	0.24	0.47	6.62	30.86	55.6
Landfill, reclamation, and restoration	15.43	2.07	--	0.39	--	0.04	0.42	18.35	33.0
Temporary stockpile	0.72	0.03	--	--	--	--	0.45	1.19	2.1
Disposal	3.81	1.06	--	0.15	--	0.01	0.09	5.12	9.2
Utilization rate in percent	48	44	100	45	100	91	87	XX	XX
Canada:									
Production	5.00	1.60	--	--	--	--	0.42	7.02	XX
Use	1.10	0.20	--	--	--	--	0.57	1.87	27.00
India:									
Production	--	--	--	--	--	--	--	90.00	XX
Use	--	--	--	--	--	--	--	11.70	13.00
Israel:									
Production	--	--	--	--	--	--	--	1.20	XX
Use	--	--	--	--	--	--	--	1.05	87.00
Japan:									
Production	6.50	1.20	--	--	--	--	1.50	9.10	XX
Use	5.25	0.90	--	--	--	--	1.50	7.65	84.00
South Africa:									
Production	1.70	--	--	--	--	--	--	1.70	XX
Use	--	--	--	--	--	--	--	--	NA

NA Not available. XX Not applicable. -- Zero.

1/ Less than 1/2 unit.

FIGURE 1
ACAA REGIONS OF THE UNITED STATES

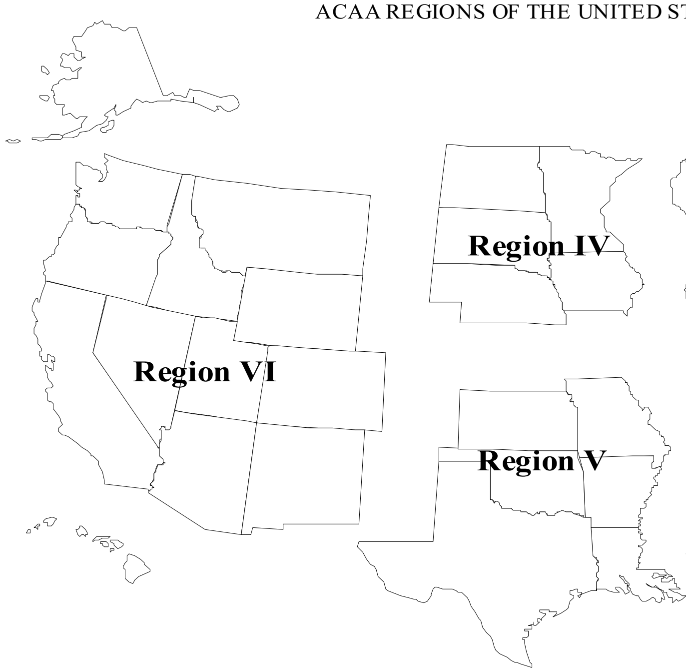
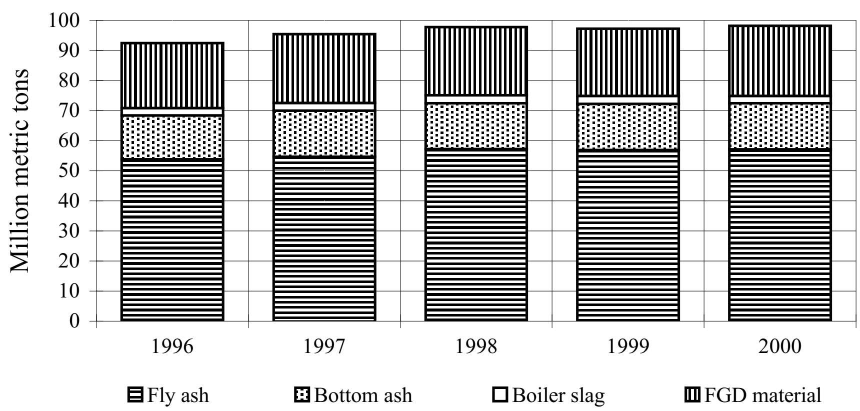
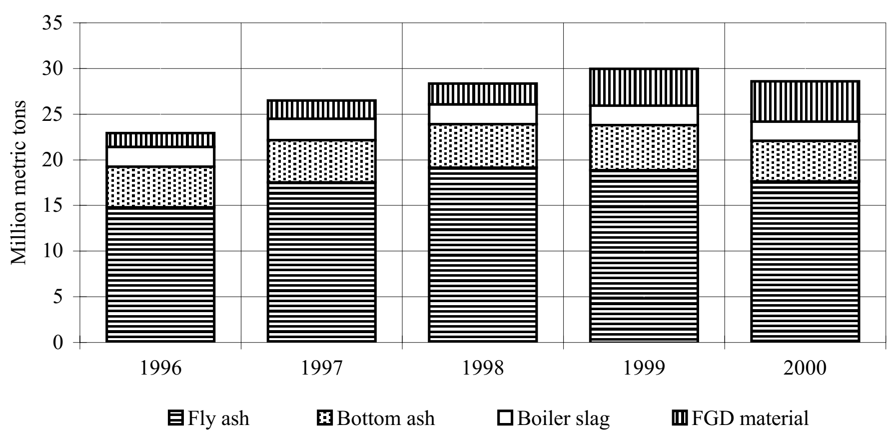


FIGURE 2
HISTORIC COAL COMBUSTION PRODUCT PRODUCTION DATA, 1996-2000



Source: American Coal Ash Association

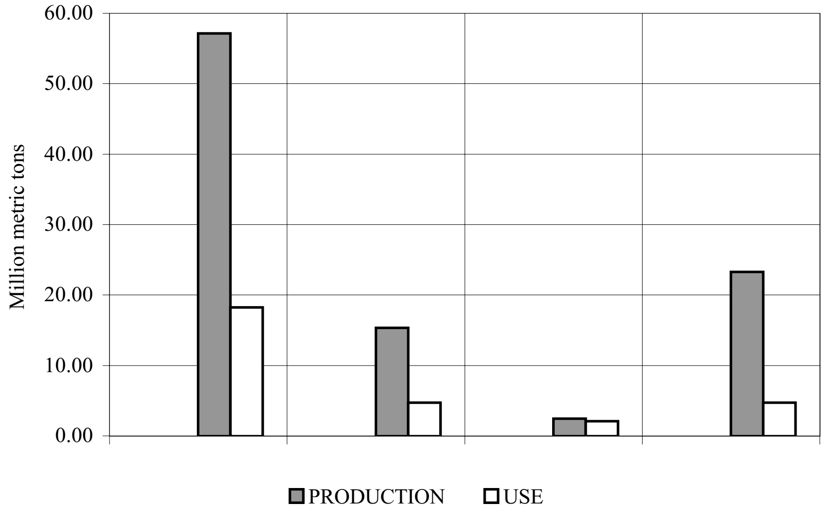
FIGURE 3
HISTORIC COAL COMBUSTION PRODUCT USE DATA, 1996-2000



Source: American Coal Ash Association

FIGURE 4

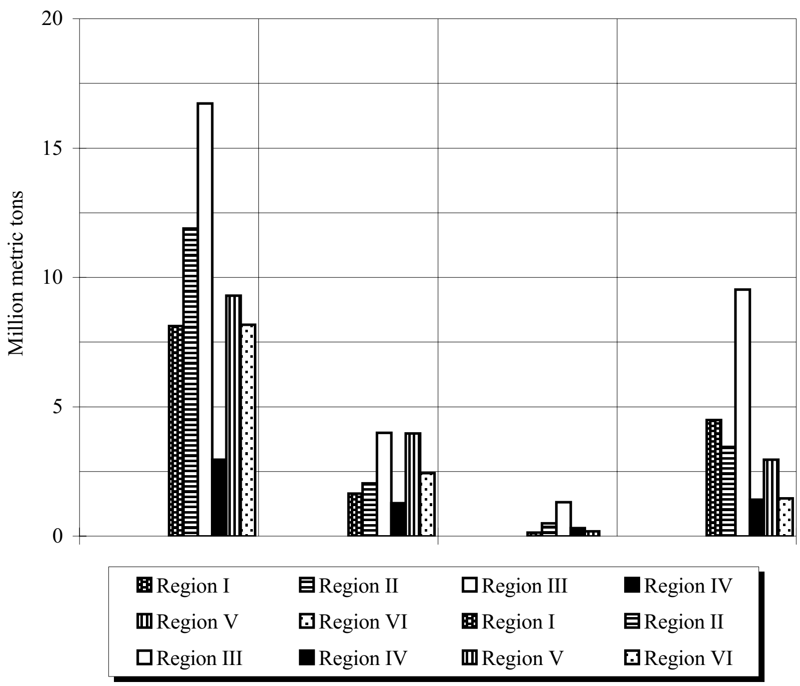
COAL COMBUSTION PRODUCT PRODUCTION AND USE FOR THE UNITED STATES, 2000



Source: American Coal Ash Association

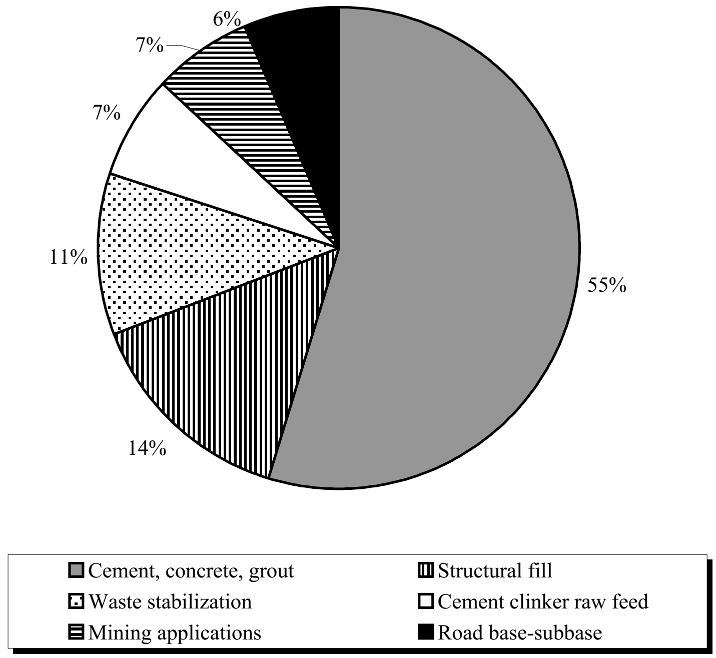
FIGURE 5

COAL COMBUSTION PRODUCT PRODUCTION BY TYPE AND REGION, 2000



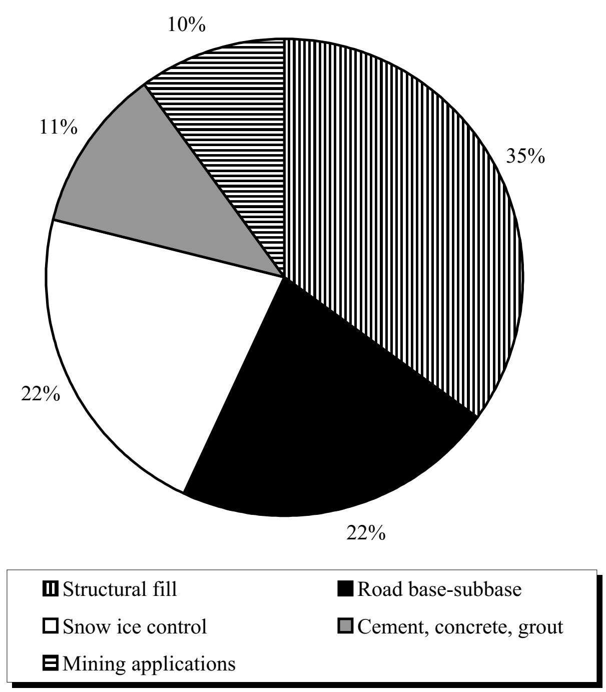
Source: American Coal Ash Association

FIGURE 6
LEADING FLY ASH USES, 2000



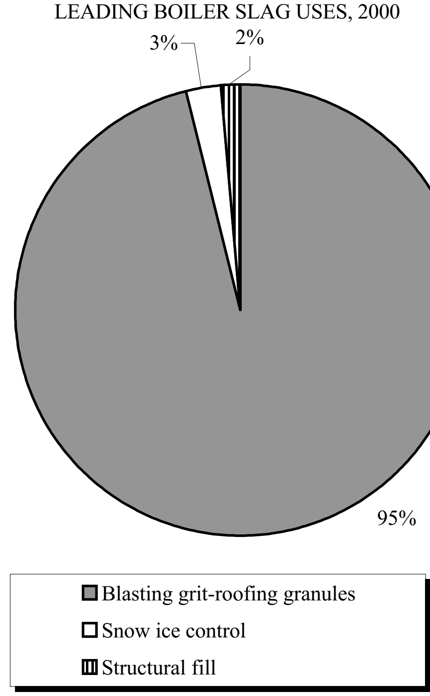
Source: American Coal Ash Association

FIGURE 7
LEADING BOTTOM ASH USES, 2000



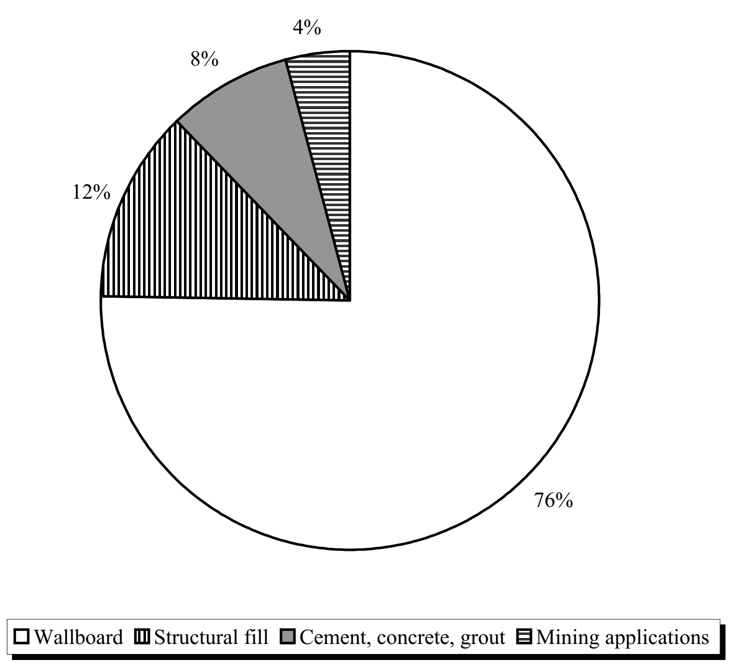
Source: American Coal Ash Association

FIGURE 8
LEADING BOILER SLAG USES, 2000



Source: American Coal Ash Association

FIGURE 9
LEADING FGD MATERIAL USES, 2000



Source: American Coal Ash Association