



# BENEFICIAL USES OF COAL FLY ASH

Annual global consumption of coal is about 6 billion tonnes, which results in the production of over 1 billion tonnes of fly ash (IEA, 2018). Coal fly ash (CFA) is extracted from the flue gas stream and then either conveyed pneumatically to a storage silo awaiting commercial use or mixed with water as conditioned ash. Governments seek to avoid accumulating conditioned CFA and so encourage alternate use. As the material and environmental benefits of including CFA in products is recognised, demand has risen and CFA is gaining commodity status. This study, one of a series on alternate uses for coal and coal by-products, focuses on the main and emerging uses of CFA from hard coal.

The geographical shift in coal power generation towards Asia has a direct impact on the production and availability of fly ash. The closure of coal stations in the USA and Western Europe means that in-country production is insufficient and there is a growing need to import fly ash leading to an expanding international market; the shortage of CFA in certain markets means that the value is increasing and is currently about 1/3<sup>rd</sup> of cement.

## CFA IN CONSTRUCTION

The dominant use of CFA is in the construction industry where it can substitute for cement clinker, replace cement in production of flowable fill and foamed concrete; and form low density manufactured aggregates, bricks, cement, and geopolymers. Projections indicate an unsustainable increase in demand for construction materials and the production of cement is the largest industrial greenhouse gas emitter. CFA substitution for cement is one way to reduce the environmental impact of the construction industry. Another reason for the increasing proportion of CFA, especially for concrete, is due to the enhanced properties of the final products that contain CFA. A key benefit is the reduction of microcracking due to thermal stress which leads to a longer lasting product that resists freeze-thaw erosion. Low density ash-based materials are suitable for the construction of passive high-rise buildings that require 40 cm thick walls, aimed at reducing the need for heating and cooling in cities.

The Indian clay brick industry consists of about 100,000 kilns which operate 24 hours a day with associated emissions, consuming around 2000 ha of fertile land. Substitution by CFA bricks largely eliminates the pollution of this industry, allowing that some cement is needed, and preserves the arable land essential to feed a growing population.

Trace levels of toxic elements are present in CFA, but analyses of granulated samples of CFA bricks and concrete demonstrated that encapsulation in a water repellent matrix results in similar leachate measurement to ash free ordinary Portland cement (OPC) materials. Mercury results from these analyses at elevated temperature are lower than background levels probably due to the presence of residual carbon.

## EXTRACTION OF METALS

Certain coals can be relatively rich in rare earth elements, recognised as critical elements for the energy transformation to renewable power, and also for aerospace industries. Once combusted, the elements are concentrated in fly ash and there are current demonstration programmes seeking economic extraction as a substitute to restricted supplies from China. In addition, CFA can be a commercial source of aluminium from alumina-rich CFA, an industrial process practiced in China. CFA is also an established source of germanium and new facilities are under construction to extract magnesium from lignite ash.

## AGRICULTURE AND LAND RECLAMATION

The UN has supported initiatives concerned with the loss of arable soils and desertification, building upon the 2015 'International Year of Soils'. Given the increasing demand for food and water, the addition of CFA to soils, especially if combined with manure, has positive benefits: controlling soil acidity; improving texture; and water retention among others. A subject of current research is the addition of CFA to soil to improve its CO<sub>2</sub> retention. The suitability of CFA for land use depends on the concentration of toxic elements, chiefly arsenic and lead, and application should be supported by leachate analysis. Practical precautions include modest deposition rates, monitoring and application intervals of several years. There is considerable experience in the use of CFA for land reclamation and mine fill; the use of CFA improves stabilisation of embankments and avoids consumption of fresh materials such as river sand.

## OTHER CFA APPLICATIONS

As an alumina silicate the composition of CFA is close to that of zeolite catalyst supports and can be adjusted to match specific crystalline structures. Zeolite catalysts account for about half of all catalysts and are important in water and gas purification. Current research is examining CFA as a suitable low-cost CO<sub>2</sub> adsorbent in pressure swing technologies to reduce the cost of CCS.

Metal composites are deployed for the protection of armoured vehicles and lightweight bodysells for electric vehicles. CFA can directly replace metals such as aluminium to lower the weight; up to 30% of the metal can be CFA while retaining the original properties of cast materials.

Addition of metal filings or carpet fibres to improve certain concrete strength characteristics is already practiced. The availability of new forms of carbon, such as graphene oxide (GO), takes this to a new level as the GO can chemically bond to ash and cement materials greatly enhancing strength and crack resistance. The inclusion of nanomaterials may mean less material is needed and the lifespan is extended.

CFA can be used as a superior proppant in shale gas recovery, where the ash can lubricate the flow into a well and offer enhanced crush resistance. CFA paper is another new product with potential. Cenospheres are a valuable low-density ash product in demand as a filler material already exhibiting sales exceeding US\$170 million per year.

The benefits of incorporating CFA into products by preserving resources, lowering material costs, building more robust structures and perhaps most significantly reducing pollutant and CO<sub>2</sub> emissions are highly advantageous, and align with UN Sustainable Development Goals to mitigate the impact of urbanisation and population growth.

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Each executive summary is based on a detailed study which is available separately from [www.iea-coal.org](http://www.iea-coal.org). This is a summary of the report: Beneficial uses of coal fly ash by Dr Ian Reid, CCC/303, ISBN 978-92-9029-626-3, 93 pp, March 2020.