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Utility bonanza from dust

Fly ash is one of the numerous substances that cause air, water and soil pollution, disrupt ecological cycles and set off environmental hazards.

The combustion of powdered coal in thermal power plants produces fly ash. The high temperature of burning coal turns the clay minerals present in the coal powder into fused fine particles mainly comprising aluminium silicate. Fly ash produced thus possesses both ceramic and pozzolanic properties.

When pulverised coal is burnt to generate heat, the residue contains 80 per cent fly ash and 20 per cent bottom ash. The ash is carried away by flue gas collected at economiser, air pre-heater and ESP hoppers. Clinker type ash collected in the water-impounded hopper below the boilers is called bottom ash.

The World Bank has cautioned India that by 2015, disposal of coal ash would require 1000 square kilometres or one square metre of land per person. Since coal currently accounts for 70 per cent of power production in the country, the Bank has highlighted the need for new and innovative methods for reducing impacts on the environment.

The process of coal combustion results in fly ash. The problem with fly ash lies in the fact that not only does its disposal require large quantities of land, water, and energy, its fine particles, if not managed well, by virtue of their weightlessness, can become airborne. Currently, 90 million tonnes of fly ash is being generated annually in India, with 65 000 acres of land being occupied by ash ponds. Such a huge quantity does pose challenging problems, in the form of land usage, health hazards, and environmental dangers. Both in disposal, as well as in utilization, utmost care has to be taken, to safeguard the interest of human life, wild life, and environment.

Is fly ash hazardous?

The physical, geotechnical and chemical parameters to characterize fly ash are the same as those for natural soils, e.g., specific gravity, grain size, Atterberg limits, compaction characteristics, permeability coefficient, shear strength parameters and consolidation parameters. The properties of ash are a function of several variables such as coal source, degree of pulverization, design of boiler unit, loading and firing conditions, handling and storage methods. A change in any of the above factors can result in detectable changes in the properties of the ash produced. The procedures for determination of these parameters are also similar to those for soils.

Engineering properties of Fly Ash	
Parameter	
Specific gravity	1.90-2.55
Plasticity	Non Plastic
Proctor compaction - Maximum dry density (gm/cc)	0.90-1.60
Optimum moisture content (%)	38.0-18.0
Angle of internal friction (O)	30^0-40^0
Cohesion (kg/cm ^{2})	Negligible
Compression index	0.05-0.4
Permeability (CM/SEC)	10^5-10^3
Particle size distribution Clay size fraction (%) Silt size fraction (%) Sand size fraction (%) Gravel size fraction (%)	 1-10 8-85 7-90 0-10
Coefficient of uniformity	3.1-10.7

Nearly 73% of India's total installed power generation capacity is thermal, 90% of it coal-based

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Fly ash produced during the burning of powdered coal in thermal power plants is a hazardous waste. However, its physical and chemical properties make it an ideal raw material for producing high quality and cost-effective bricks, interlocking pavers, kerbstones and mosaic tiles.

Rajiv Gandhi Rural Housing Corporation Ltd. has done pioneering work in using fly ash products in the projects implemented by it. Fly ash-based building components like blocks, bricks, door and window frames are extensively used in the construction of houses in Raichur, Bellary, Uttara Kannada and Shimoga Districts. Raichur Nirmiti Kendra received an award from HUDCO for use of industrial waste as building material.

The effort of ENVIS Centre, Karnataka, to popularize the use of fly ash products is laudable.

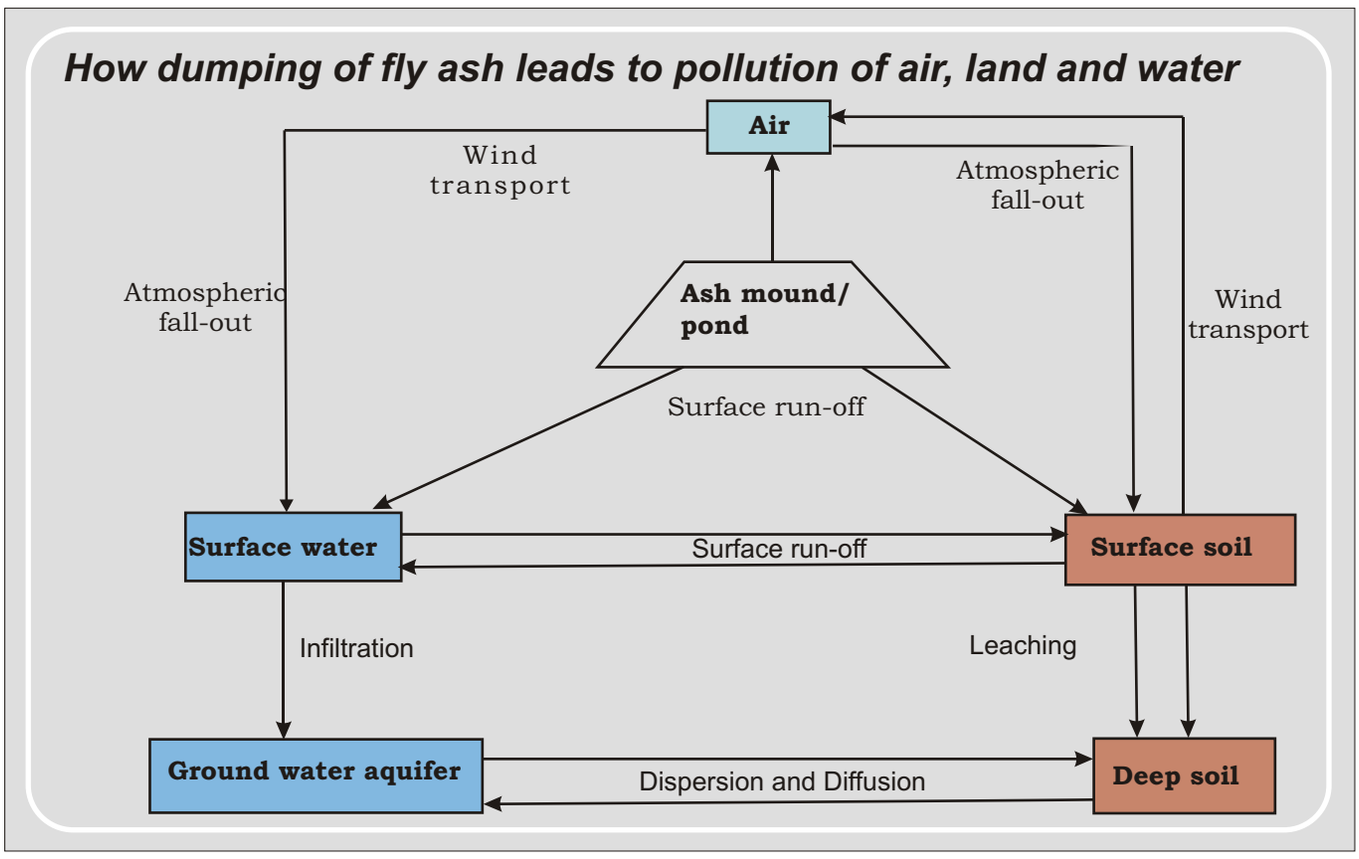
(Nilaya Mitash)

How fly ash is hazardous

Fly ash is a very fine powder and tends to travel far in the air. When not properly disposed, it is known to pollute air and water, and causes respiratory problems when inhaled. When it settles on leaves and crops in fields around the power plant, it lowers the yield.

The conventional method used to dispose of both fly ash and bottom ash is to convert them into slurry for impounding in ash ponds around the thermal plants. This method entails long-term problems.

The severe problems that arise from such dumping are:



India would require 1000 sq Km / 1 Sq m per person for disposal of coal ash by 2015.

Raichur Thermal Power Station, Raichur

- The construction of ash ponds requires vast tracts of land. This depletes land available for agriculture over a period of time.
- When one ash pond fills up, another has to be built, at great cost and further loss of agricultural land
- Huge quantities of water are required to convert ash into slurry.

During rains, numerous salts and metallic content in the slurry can leach down to the groundwater and contaminate it.

Disposal problem

The Raichur Thermal Power Station (RTPS), one of Karnataka's major power plants, is situated at Shakthinagar near Devasugur village in Raichur District. Owned by Karnataka Power Corporation Limited (KPCL), RTPS consists of seven units, each capable of generating 210 MW of power. Its total power generation at optimum capacity is 1470 MW per day. RTPS is the power-generating hub of Karnataka and meets 75 per cent of the state's power demand.

India has about 70 thermal power plants and 70 per cent of them burn coal to generate power. Various Indian collieries supply the coal, which is known to have a very high ash content of almost 40 to 45 per cent.

India's thermal power plants produce an estimated 100 million tonnes of fly ash per annum. Of this, RTPS alone generates about 1.5 million tonnes at 4,000 tonnes daily. Out of this, 80 per cent is fly ash and 20 per cent bottom ash. This ash needs to be disposed of every day.

Primarily, the fly ash is disposed of using either dry or wet disposal scheme. In dry disposal, the fly ash is transported by truck, chute or conveyor at the site and disposed of by constructing a dry embankment (dyke). In wet disposal, the fly ash is transported as slurry through pipe and disposed of in impoundment called "ash pond". Most of the power plants in India use wet disposal system, and when the lagoons are full, four basic options are available:

- constructing new lagoons using conventional construction material,
- hauling of fly ash from the existing lagoons to another disposal site,
- raising the existing dyke using conventional constructional material, and
- raising the dyke using fly ash excavated from the lagoon ('ash dyke').

The option of raising the existing dyke is very cost effective because any fly ash used for constructing dyke would, in addition to saving the earth filling cost, enhance disposal capacity of the lagoon.

An important aspect of design of ash dykes is the internal drainage system. The seepage discharge from internal surfaces must be controlled with filters that permit water to escape freely and also to hold particles in place and the piezometric surface on the downstream of the dyke. The internal drainage system consists of construction of rock toe, 0.5m thick sand blanket and sand chimney. After completion of the final section including earth cover the turfing is developed from sod on the downstream slope.

Fly Ash Mission:

The Government of India, through the Department of Science and Technology, has initiated the Fly Ash Mission, under TIFAC. The mission propagates various developments in the area of fly ash utilization carried out by the R & D institutes in India. Besides, the political will to encourage the use of fly ash has risen perceptibly.

The Fly Ash Mission was commissioned in 1994 with the Department of Science & Technology (DST) as the nodal agency and Technology Information and Assessment Council (TIFAC) as the implementing agency, in view of the overall concern for the environment and the need for the safe disposal and effective utilization of fly ash.

Technology Project in Mission Mode (TPMM)

The Ministry of Environment & Forest (MoEF), Ministry of Power, thermal power stations, R&D institutions and industry together have launched a Technology Project in Mission Mode (TPMM). Their focus is on the demonstration of coal ash related technologies for infusing confidence and thus ensuring large-scale adoption. The industry, R&D institutions and academia have obtained encouraging results from several projects they have taken up. Some of these projects have been completed, multiplier effects have started and other projects are heading towards meaningful completion. A

Filling fly ash into trucks

judicious mix of thrust areas has been taken up for concerted efforts. These include fly ash characterization; hydraulic structures; handling and transportation; agriculture related studies and application; ash ponds and dams, reclamation of ash ponds for human settlement, roads and embankments, underground mine fills and related research projects.

Utilization is a viable alternative to dumping

Several factors have impeded fly ash utilization in India, while it is being extensively used globally. Coal-based thermal power stations have been operational for more than 50 years but the concept of developing environment-friendly solutions for fly ash utilization is only about 15 years old. Overall fly ash utilization in India stands at a fairly low level of about 15 per cent of the quantity generated. Various possibilities for its use are under research. Among numerous factors that account for the low level of utilization, the chief factors are:

- Poor understanding of the chemistry of fly ash and its derivatives for proper end applications
- Absence of standards and specifications for fly ash products
- Lack of reliable quality assurance for fly ash products
- Poor public awareness about the products and their performance
- Non-availability of dry fly ash collection facilities
- Easy availability of land with top soil at cheap rates for manufacturing conventional bricks
- Lack of proper coordination between thermal plants and ash users.

Fly ash utilization in the country is gaining momentum owing to the stringent regulations that the MoEF has stipulated, as also to increased awareness about the benefits of using fly ash for various products.
Fly ash from coal-fired thermal power stations is an excellent potential raw material for the manufacture of construction material like blended cement, fly ash bricks, mosaic tiles and hollow blocks. It also has other, high volume applications and can be used for paving roads, building embankments, and mine fills.

Fly ash products have several advantages over conventional products. The use of cement in the manufacture of construction products can be reduced by substitution with fly ash. While the use of cement cannot be completely avoided, for certain products like tiles, the substitution can go up to 50 per cent. These products are known to be stronger and more cost-effective because of substantial savings on raw material.

Fly ash products are also environment-friendly. A case in point is fly ash bricks. The manufacture of conventional clay bricks involves the consumption of large amounts of clay. This depletes topsoil and degradation of agricultural land. Fly ash bricks do not require clay and serve two purposes; preservation of topsoil and constructive utilization of fly ash.

Agricultural uses of fly ash

Research on agricultural uses of fly ash has been going on in universities and research institutes (see box) across the country for several years.

The same fly ash that causes harm when it settles on leaves, can prove beneficial when applied scientifically to agricultural fields. It can be a soil modifier and enhance its moisture retaining capacity and fertility. It improves the plant's water and nutrient uptake, helps in the development of roots and soil-binding, stores carbohydrates and oils for use when needed, protects the plants from soil-borne diseases, and detoxifies contaminated soils.

Efffect of fly ash on yield of crops

Name of crop	Per cent increase
Groundnut	40.2
Sunflower	25
Safflower	15.2
Maize	12
Paddy	10.5 - 18.0

Yields are also known to increase, as experiments on groundnut, sunflower, linseed and other oilseeds have shown.

Fly ash as fill material

Large scale use of ash as a fill material can be applied where

- Fly ash replaces another material and is therefore in direct competition with that material.
- Fly ash itself is used by the power generating company producing the fly ash to improve the economics of the overall disposal of surplus fly ash.

Conversion of fly ash into wealth generator

(Excerpt from President A P J Abdul Kalam's address to the nation on the eve of the country's 56th Republic Day):

"As you are aware, the use of coal for power generation results in an increased quantum of fly ash production, which has reached about 100 million tonnes per year. All out efforts are needed to utilize this fly ash not only from environmental considerations, but also to avoid land usage for fly ash dumping. Though there has been a steady progress in fly ash utilization from 1990, we have a long way to go to reach the target of 100 per cent fly ash utilization. It is reported that the agricultural increase of grains is around 15 per cent, green vegetables 35 per cent and root vegetables 50 per cent, when fly ash is mixed with soil. Toxicity tests have proved that there is no toxic element due to fly ash. But it has higher nutrients due to increased availability of iron and calcium. Fly ash can become a wealth generator by making use of it for producing 'green building' materials, roads, agriculture etc. Full utilization of the generating stock will provide employment potential for three hundred thousand people and result in a business volume of over Rs.4,000 crore."

- Higher ultimate strength
- Increased durability
- Improved workability
- Reduced bleeding
- Increased resistance to sulfate attack
- Increased resistance to alkali-silica reactivity
- Reduced shrinkage.

Fly ash utilization, especially in concrete, has significant benefits including: (1) increasing the life of concrete roads and structures by improving concrete durability, (2) net reduction in energy use and greenhouse gas and other adverse air emissions when fly ash is used to replace or displace manufactured cement, (3) reduction in amount of coal combustion products that must

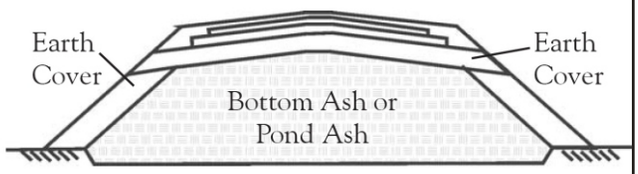
- Fly ash disposal is combined with the rehabilitation and reclamation of land areas desecrated by other operations.

Fills can be constructed as structural fills where the fly ash is placed in thin lifts and compacted. Structural fly ash fills are relatively incompressible and are suitable for the support of buildings and other structures. Non-structural fly ash fill can be used for the development of parks, parking lots, playgrounds and other similar lightly loaded facilities. One of the most significant characteristics of fly ash in its use as a fill material is its strength. Well-compacted fly ash has strength comparable to or greater than soils normally used in earth fill operations. In addition, fly ash possesses self-hardening properties which can result in the development of shear strengths. The addition of illite or cement can induce hardening in bituminous fly ash which may not self-harden alone. Significant increases in shear strength can be realized in relatively short periods of time and it can be very useful in the design of embankments.

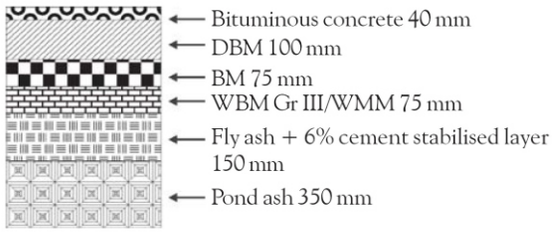
Fly ash in portland cement concrete

Fly ash can be used in portland cement concrete to enhance the performance of the concrete. Portland cement is manufactured with calcium oxide (CaO), some of which is released in a free state during hydration. As much as 20 pounds of free lime is released during hydration of 100 pounds of cement. This liberated lime forms the necessary ingredient for reaction with fly ash silicates to form strong and durable cementing compounds, thus improves many of the properties of the concrete. Some of the resulting benefits are:

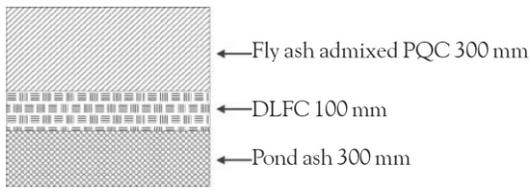
Fly ash road embarkment



Typical cross section of fly ash road embarkment



Typical cross section of flexible pavement - using fly ash



Typical cross section of regid pavement - using fly ash

be disposed in landfills, and (4) conservation of other natural resources and materials. Typically, 15 to 30 per cent of the portland cement is replaced with fly ash.

Fly ash for roads

Fly ash can be used for construction of road and embankment. This utilization has many advantages over conventional methods.

- Saves top soil which otherwise is conventionally used
- Avoids creation of low lying areas (by excavation of soil to be used for construction of embankments)
- Avoids recurring expenditure on excavation of soil from one place for construction and filling up of low lying areas thus created.
- Does not deprive the nation of the agricultural produce that would be grown on the top soil which otherwise would have been used for embankment construction.
- Reduces the demand of land for disposal/deposition of fly ash that otherwise would not have been used for construction of embankment.
- Controls the source of pollution.

Manufacturing process of a typical fly ash product

Mosaic tile manufacture involves preparing the mix for two layers: the wearing layer and the base layer. The wearing layer consists of a plastic mix of mosaic chips, cement, and fly ash and dolomite powder. The base layer consists of a semi-dry mix of fly ash, cement and quarry dust. The tiles are pressed in the tile-making machine and air-dried for 12 hours or more. They then undergo curing

CASHUTEC and INEP

One small step in addressing this issue. Special thanks to the Indo-Norwegian Environment Programme (INEP) for setting up the Centre for Ash Utilization Technologies and Environment Conservation (CASHUTEC) at the Raichur Thermal Power Station and thereby combating the fly ash hazard.

The establishment of CASHUTEC at the Raichur power station is one of the several projects that INEP has initiated in Karnataka. Through its projects, it aims to address air, water and soil pollution and promote sustainable solutions. All INEP projects are pilot in nature and contribute to sustainable management of natural resources.

The project at RTPS had the following objectives :

- Establishing a self-sustaining fly ash utilization demonstration centre
- Functioning as a nodal centre for development, demonstration, training and transfer of technologies for fly ash utilization in India
- Bringing increased awareness among entrepreneurs and various end users about the benefits of using fly ash products
- Reducing potential threats of air and water pollution
- Ensuring the ecological and environmental stability of areas surrounding RTPS
- Reducing pressure on land requirements for fly ash dumping.

Financial Outlay of the Project	
Phase one	
Total cost	Rs.580.00 lakhs
INEP assistance	Rs.225.00 lakhs
KPCL contribution	Rs.355.00 lakhs
Duration	Two years
Phase two	
Total cost	Rs.26.00 lakhs
INEP assistance	Rs.19.00 lakhs
CASHUTEC contribution	Rs.7.00 lakhs
Duration	18 months

Objectives of CASHUTEC

CASHUTEC itself was established with the broad objectives of:

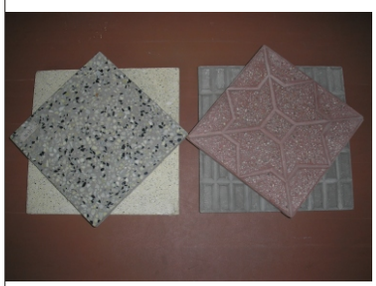
- Conducting R & D programmes on uses of fly ash
- Demonstrating manufacture of fly ash building products
- Demonstrating high volume uses of fly ash in cement, concrete, agriculture and building of roads
- Generating increased awareness on the benefits of using coal ash products among entrepreneurs and various end-users from four of Karnataka's northern districts, Raichur, Bellary, Gulbarga and Dharwad
- Enabling semi-commercial production of bricks, blocks, pavers and mosaic tiles for self-sustenance of the centre
- Developing a strong brand for products manufactured at the centre.

Techno economic analysis and comparative study of fly ash products manufactured at CASHUTEC			
Fly ash Product	**Characteristics**	**CASHUTEC**	**Convential**
Brick (9 x 4.25 x 3) inches	Finish	Excellent	Satisfactory
	Compressive strength	65 - 100 kg/cm2	50 kg/cm2
	Water absorption	10 - 12%	15 - 20%
Block (16 x 8 x 8) inches	Finish	Excellent	Satisfactory
	Compressive strength	50 kg/cm2	35 kg/cm2
	Water absorption	10 - 12%	13 - 15%
Interlocking paver	Finish	Excellent	Good
	Compressive strength	170 - 280 kg/cm2	150 - 200 kg/cm2
	Water absorption	10 - 12%	0.15
Kerbstone	Finish	Excellent	Good
	Compressive strength	215 kg/cm2	150 kg/cm2
	Water absorption	8 - 10%	
Mosaic tile	Finish	Excellent	Good
	Transverse Strength	15 kg/cm2	30 kg/cm2
	Water absorption	3 - 4%	0.1
	Abrasion resistance	1.75 mm	3.5 mm

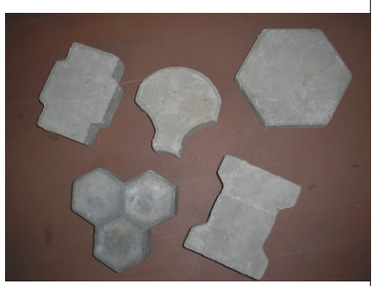
Fly ash products manufactured at CASHUTEC, Raichur

Fly ash blocks

Fal-G blocks



Mosaic tiles



Interlocking pavers

Evaluation results of fly ash mosaic tiles		
Properties	**Fly ash mosaic tiles**	**IS 1237/CPWD specs**
Wet transverse strength (N/sq. mm)	4.5	Not less than 3.0 N/sq. mm when full size tiles are tested
Water obsorption(%)	3.3	Not to exceed 10% when full size tiles are tested
Abrasion resistance (mm)	1.75	Not to exceed 3.5 mm for general purpose. Not to exceed 2.0 mm for heavy duty tiles.

in water tanks for 15 days. The tiles are then polished and stacked for supply.

While the procedure may be similar to the conventional method, the substitution of cement with fly ash by up to 30 per cent serves as value addition. Fly ash is used in both layers of a mosaic tile. Several benefits accrue from this. Fly ash turns from a problem ridden byproduct into a component of a utility product comparable to conventional products in strength and aesthetics. Fly ash tiles, for example, can be used for heavy-duty floors too. The table below suggests that the properties of fly ash mosaic tiles are far superior to those of conventional tiles.

FAL-G (fly ash-lime-gypsum)

Fal-G bricks and blocks are manufactured without using thermal energy, in contrast to the sintering involved in the production of clay bricks.

How do these bricks get strength, if they are not baked?

Fal-G bricks are made of a mixture of fly ash-lime-gypsum or fly ash-cement-gypsum. In either combination, Fal-G is a hydraulic cement, which means it sets and hardens in the presence of moisture, on the lines of ordinary portland cement, gaining strength progressively over ageing. Nearly 200 tonnes of coal is used to sinter one million clay bricks, a process that generates over 350 tonnes of carbon dioxide (CO2). The production process of

Fal-G bricks eliminates harmful emissions of this scale. This would also be the amount of carbon credit earned

Seetha Subbaraju memorial hall in Raichur constructed using fly ash products

Frequently Asked Questions

What is fly ash?
Fly ash is a fused residue of clay minerals present in coal. The high temperature generated when coal burns in thermal power plants, transforms the clay minerals in coal powder into a variety of fused fine particles of mainly aluminium silicate composition.

Is fly ash harmful?
Fly ash is a very fine powder and tends to travel in the air. When not properly disposed of, it pollutes air and water, and causes respiratory problems when inhaled. When it settles on leaves and crops in agriculture fields around the power plant, it lowers the yield.

Where and how can fly ash be sourced?
Fly ash can be sourced free of cost from RTPS, Raichur in Karnataka .

Which is the nodal agency for all fly ash related queries?
CASHUTEC at Shaktinagar, Raichur is the nodal agency for all queries related to fly ash utilization. This includes technical know-how, queries about technology, machinery, manufacture and usage.

What makes fly ash useful?
Fly ash is most commonly used as a pozzolan in PCC applications. Pozzolans are siliceous or siliceous and aluminous material, which in a finely divided form and in the presence of water, react with calcium hydroxide at ordinary temperatures to produce cementitious compounds.

What are Carbon credits?
Carbon credits are certificates awarded to countries that are successful in reducing the emissions that cause global warming. For trading purposes, one credit is considered equivalent to one tonne of carbon dioxide emission reduced. Such a credit can be sold in the international market at a prevailing market rate. The trading can take place in open market. Developed countries that have exceeded the levels can either cut down emissions, or borrow or buy carbon credits from developing countries. However there are two exchanges for Carbon credit viz Chicago Climate Exchange and the European Climate Exchange.

Is it possible to set up industries to manufacture products similar to those produced by CASHUTEC?
Yes, CASHUTEC provides complete technical and commercial consultancy for prospective entrepreneurs who wish to set up industries for the manufacture of fly ash products.

Is it possible to procure products manufactured at CASHUTEC?
Yes, it is possible to order and procure products from CASHUTEC, or through the GRASIM Industries dealer network.

Source:

[1]Using fly ash Extracting value from waste Published by INEP.
[2] Extract from paper 'Technology: Fly ash Disposal and Utilization: The Indian Scenario' by Rajiv Sinha, Department of Civil Engineering, IIT Kanpur
[3] Excerpt from Kiln Economics, Down to Earth July 15, 2005
[4] Wikipedia.org
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