The use of coal ash in road construction

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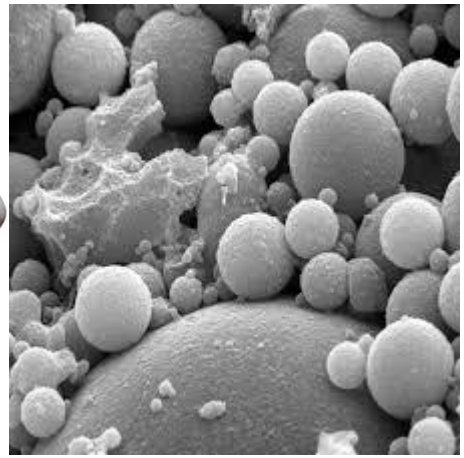
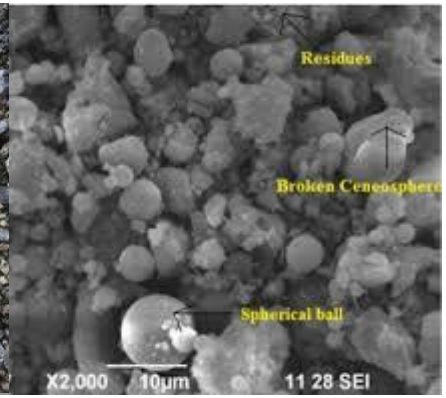
Coal Ash

- Grey powder formed by inorganic matter after combustion of coal.

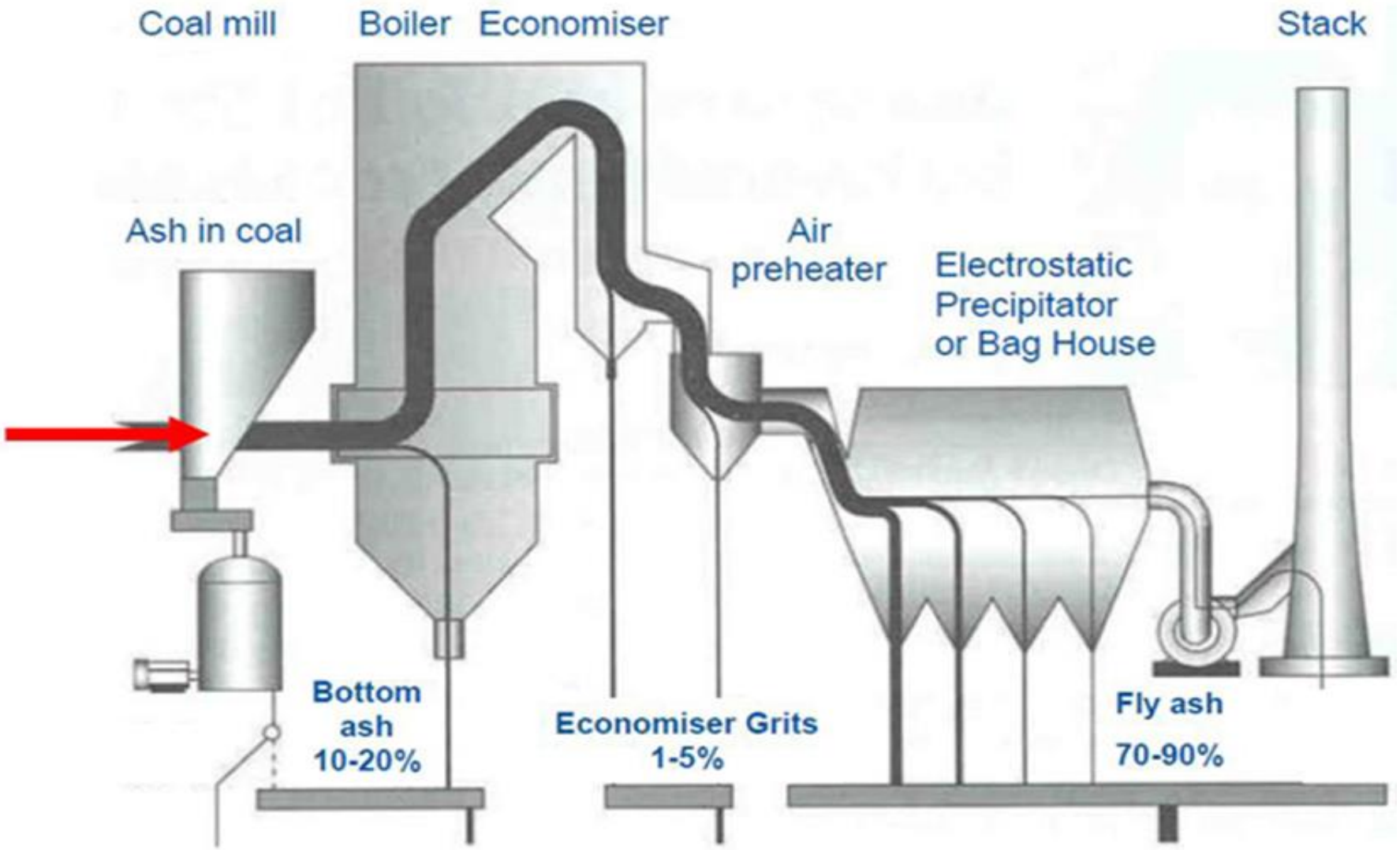
- Fly ash
  - Small, fine particles (0.01-100µm diameter)
  - 80-90%
  - Spherical glass aluminosilicate
  - Captured by ESP or bag filters



- Coarse / Bottom ash
  - Heavier particles
  - 10-20%
  - Base of the boiler
  - Collected by submerged scraper conveyor



Coal Ash


Coal mill
Boiler
Economiser
Stack
Ash in coal
Air
preheater
Electrostatic
Precipitator
or Bag House
Bottom
ash
10-20%
Economiser Grits
1-5%
Fly ash
70-90%

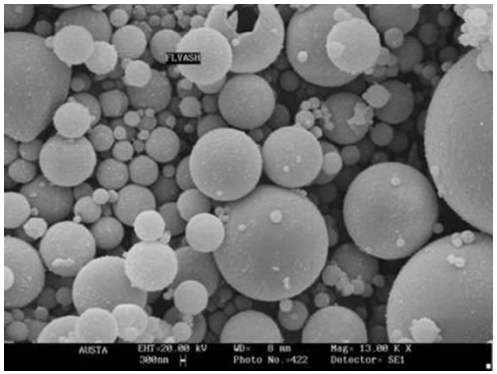
Coal Ash

- Obtains physical and mineralogical properties from
  - Parent coal
  - Combustion conditions
    - Temperature
    - Air : fuel
    - Milling
    - Rate of combustion
  - Emission control techniques
  - Climate
- Classified as Class C (calcareous) or **Class F (siliceous) ashes**

Properties	Fly Ash Classes	
Silicon dioxide, aluminium oxide, iron oxide	Class F	Class C
($SiO_2 + Al_2O_3 + Fe_2O_3$), min, wt. %	70,0	50,0
Sulphur trioxide (SO_3), max, wt. %	5,0	5,0
Moisture content, max, wt. %	3,0	3,0
Loss on ignition, max, wt. %	6,0	6,0

Coal Ash

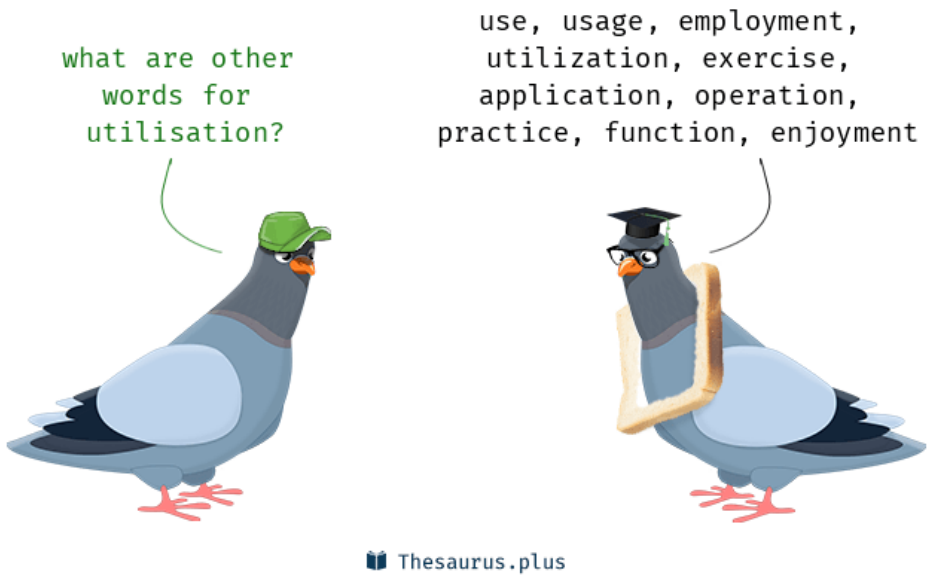
- SA has mostly sub-bituminous coal forming ash which is
  - Highly alkaline (pH 11.5-12)
  - Low iron content
- Eskom ash is unique worldwide
  - Size and pressure of the boilers
  - Combustion techniques
  - Poor quality coal used
  - Ash
    - Highly alkaline
    - Low sulphur
    - Low carbon
    - Pozzolanic



- Beneficiation relies on one or more of the properties
  - Spherical shape
  - pH
  - Pozzolanic Reactivity
  - Variety of particle sizes

Research

- 30 plus years
- Several different phases
- Ash Utilisation
- Ash Applications
- Ash Beneficiation



Acknowledgement

Acknowledge Dr Martin Mngangira and his team from the CSIR for the following information collected for the Eskom funded **ASH IN ROAD CONSTRUCTION** project.

ESKOM & CSIR
Fly Ash Utilisation Project: Road Construction

WHY?

- Generate additional knowledge through a detailed research programme in the use of fly ash as a substitute for conventional materials for road construction

- Based on the findings, develop toolkit/s with guidance for the utilisation of the ash, in terms of technical and environmental considerations:

  - to provide road industry with the most appropriate tool through which they can make informed decisions.

Road Construction – Eskom CSIR research

Fly ash utilisation in road construction

Basic laboratory studies

Fly ash characterisation

Detailed laboratory studies

Variability testing

Strength behaviour

Chemical and environmental

Trial sections

Monitor response due to HVS trafficking

Long-term performance assessment

Pavement Design

Technical Guideline for the use of Fly Ash in Road Construction

India

- Fly ash mandatory utilisation area extended from 100 km to 300 km - 2016
- Every construction agency engaged in the construction of buildings within a radius of 300 km from power plant was required to use only fly ash-based products
- Till 100 km power plants will bear the cost, b/w 100-300 km it should be shared equally

India Established specifications

Use of fly ash in road and embankments construction (IRC:58:2001).

No.	Parameter	Fly Ash	Natural Soil
1	Bulk Density (gm/cc)	0.9-1.5	1.3-1.8
2	Shrinkage Limit	Higher	Could be lower
3	Grain Size	Major fine sand / silt & small per cent of clay size particles	Sand / silt / clay size particles depending upon type of soil
4	Clay (per cent)	Negligible	Depends on type of soil
5	Free Swell Index	Very low	Variable
6	Classification (Texture)	Sand silt to silty loam	Sandy to clayed silty loam
7	Water Holding Capacity (WHC) (per cent)	40-60	05-50
8	Porosity (per cent)	30-65	25-60
9	Surface Area (m^2/kg)	500-5000	-
10	Lime reactivity (MPa)	1-8	Variable

Engineering Properties

Parameter	Fly Ash	Sand	Silt	Clay
Specific gravity	1.9-2.55	2.65-2.7		
Plasticity index	NP	NP	NP to 7	>17
Compaction test Maximum Dry Density (gm/cc)	0.90-1.60	1.75-1.84	1.52-2.00	1.45-1.8
Optimum moisture content (%)	38-18.0	15-9	18-10	30-15
Angle of internal friction (Ø)	30°-40°	28°-45°	25°-35°	30°-60°
Cohesion (kN/m^2)	Negligible	0	10-25	30-60
Compression index	0.05-0.4	-	0.05-0.15	0.30-1.50
Permeability (cm/sec)	10^{-3}-10^{-5}	10^{-2}-10^{-4}	10^{-5}-10^{-7}	≤10^{-7}

India Engineering properties

To be evaluated before using fly ash for **embankment construction** (IRC, 2001; FARC, 2015):

- Particle size distribution;
- maximum dry density;
- Shear strength;
- Permeability, and
- Drainage properties.

India

- most often considered to be a bitumen extender, with the extent of replacement varying between replacements of 10% to 60% of bitumen
- considered to replace fine aggregate or common filler portion of the asphalt mixture.

Base courses or wearing courses for heavy traffic corridors or for low traffic volume roads

- Improving workability of concrete;
- Increase in the durability of concrete mixture;
- Reduction in alkali-aggregate reaction;
- Reduction in thermal cracking;

Australia *How are they doing it*

Developed guidelines for the use of coal combustion products: ADAA

Grades of fly ash as defined by the Australian Standard AS3582.1 (fine, medium and coarse)

Grade	Fineness by mass % passing 45µ sieve	Loss of ignition (% maximum)	Moisture content (% maximum)	SiO_2 content (% maximum)
Fine	75	4	1	3
Medium	65	5	1	3
Coarse	55	6	1	3
Test Method	AS3583.1	AS3583.3	AS3583.2	AS3583.8

Australia

- Ingredient in soil modification and/or stabilisation
- Component in road bases, subbases, and pavement
- Where settlement of the sub grade is of concern in embankments on soft or poor ground conditions
- Aggregate in road bases, subbases, and pavement
- Engineering Properties

MDD (t/m^3)
Void ratio
OMC (%)
Breakage Index, BI(%)
Fines content after compaction (%)
CBR (%)
UCS at OMC (kPa)
Collapse Potential (%)

Europe

- Soil beneficiation with fly ash (EN 14227-13)
- Fly ash bound mixtures (EN 14227 – part 3)
- Fly ash for hydraulically bound mixtures (EN14227 – part 4)
- Use in hydraulic road binders the requirements of the European standard EN 13282
- The requirements for fly ash are based on the definitions given in the cement standard EN 197-1

Applications of national and / or country specific regulations of road construction authorities

USA The categories relating to road applications are:

I. Use in concrete products;

II. Embankments;

III. Road base and sub-base;

IV. Soil stabilization;

V. Mineral Filler in asphalt and;

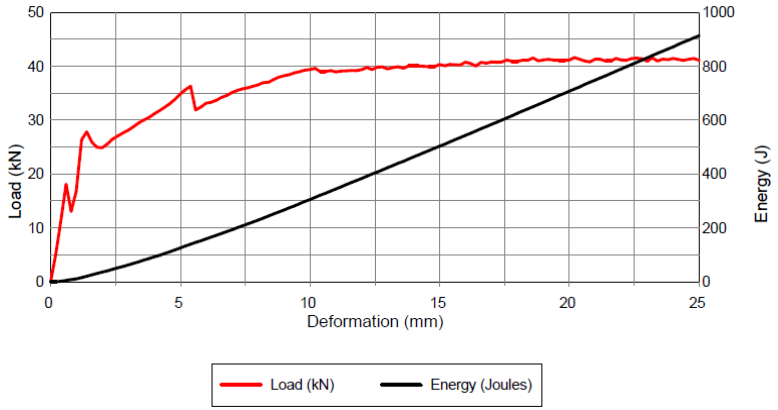
VI. Aggregate.

ARC Engineering
Underground Road Construction

1. Utilisation of Activated FA, slag and water – 80MPa in 28 days.
   - Max of an 8 hour delay for placement.
2. Shotcrete – 1-1.5 MPa in 3 sec

This is the same base material but varying activators!

- Utilised 50% underground materials
- Transported the activator only
- Decreased costs by 75%
- Decreased CO_2 production by 350kg/m placed.
- Low wear
- 15-16MPa flexural strength
- 50MPa compressive strength



ARC Engineering
Soil stabilisation

Using:

2% - OPC

0.5% - Activator

97.5% - dumped coal ash

Formed stabilised area:

2.5MPa after 24 hours

5MPa after 28 days

ARC Engineering Pavers

Using:

Fly Ash, Aggregate, Inorganic polymer and activator catalyst

Formed:

15 - 22MPa after 24 hours

40 - 45MPa after 28 days

50% decrease in cost.

ARC Engineering
0% cement concrete

Using:

Fly Ash, slag base, NaOH (dangerous)

Offered:

Decreased shrinkage – 10% of normal

51MPa compressive strength and 4.2MPa flexural strength after 28 days.

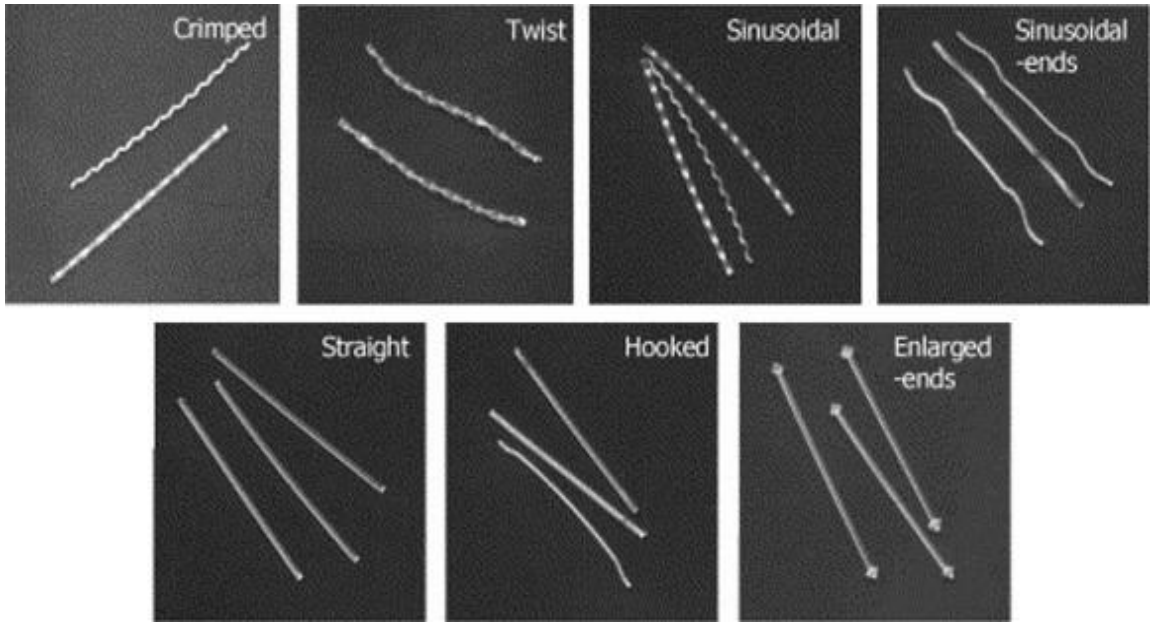
Decreased cost of materials by 30% and labour by 25%.

ARC Engineering
Test road – on going project

To form a 1km rigid pavement. With concrete, base and sub base layers

Using:

Dumped Ash, slag base, macro fibres to replace metal reinforcing.



THANK YOU

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