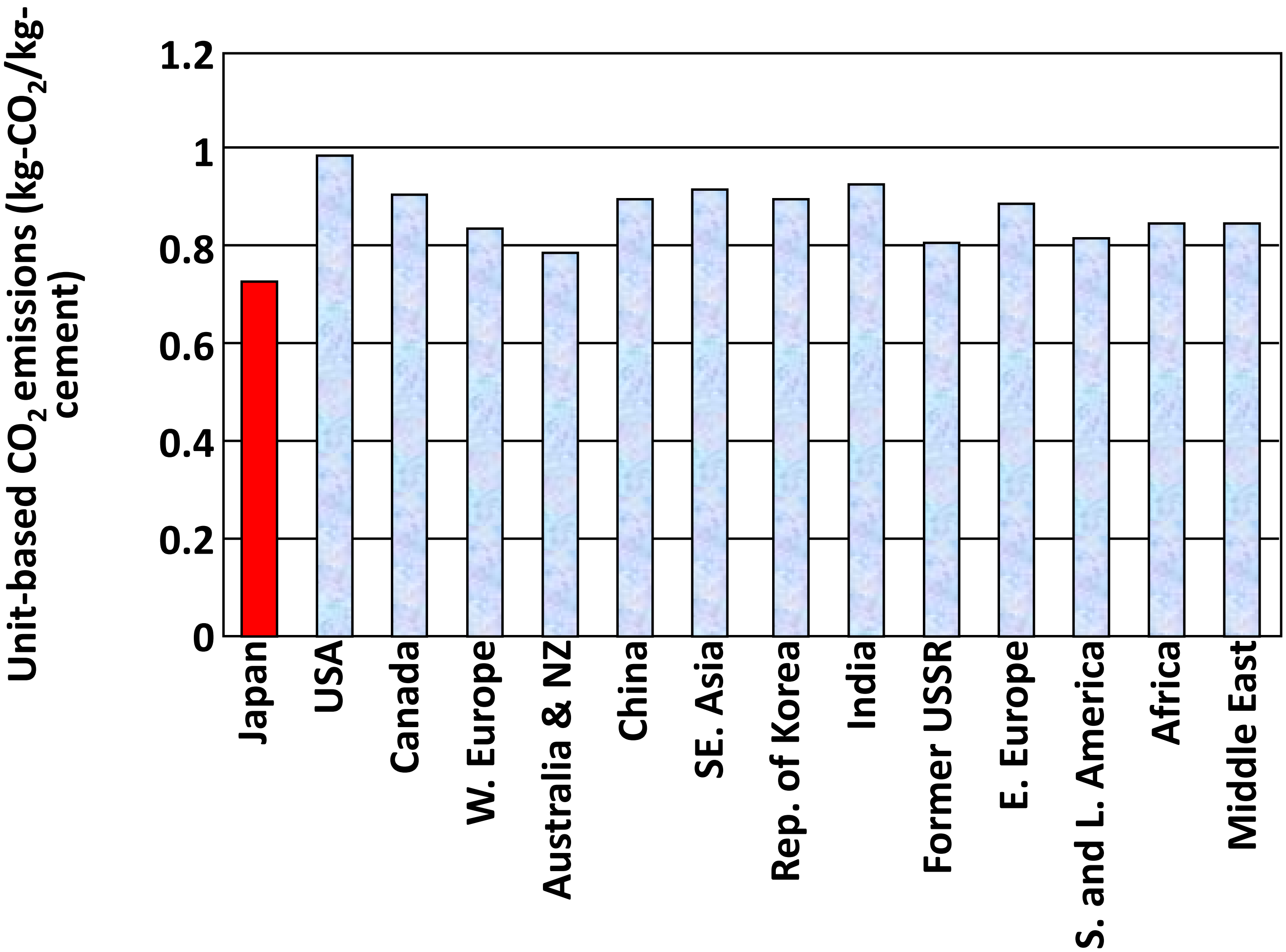
Reducing the Environmental Impact of Concrete

Professor Peter Claisse. Coventry University.

Esmaiel Ganjian, Homayoon Pouya, Seema Karami,
Juan Lizarazo Marriaga, Asma Shebani

- The extent of the problem
- Current solutions (replacing some of the cement)
- Current research on new ideas (replacing all of the cement)

Unit-based CO_2 Emission in Cement Manufactures



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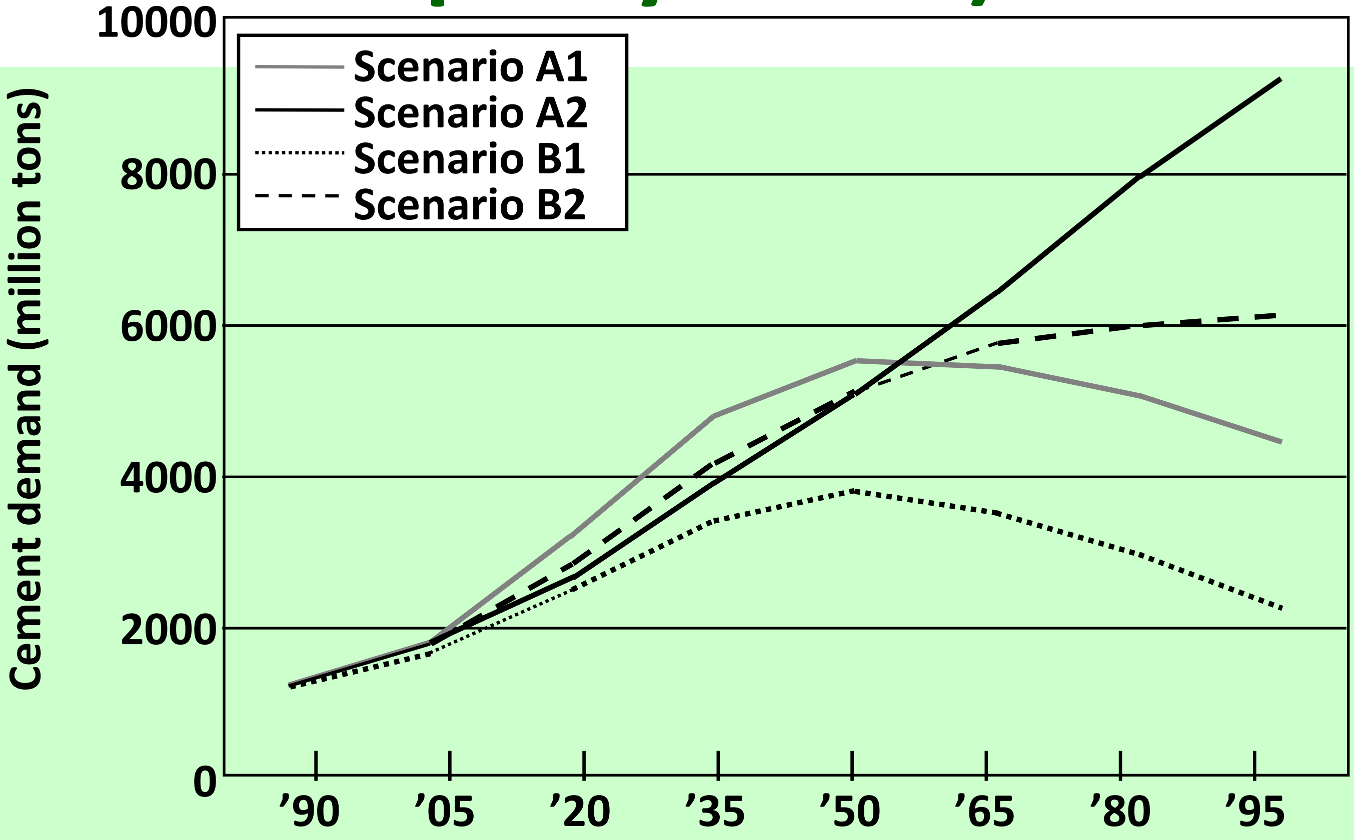
Estimated Cement Demand (by Humphreys et al.)



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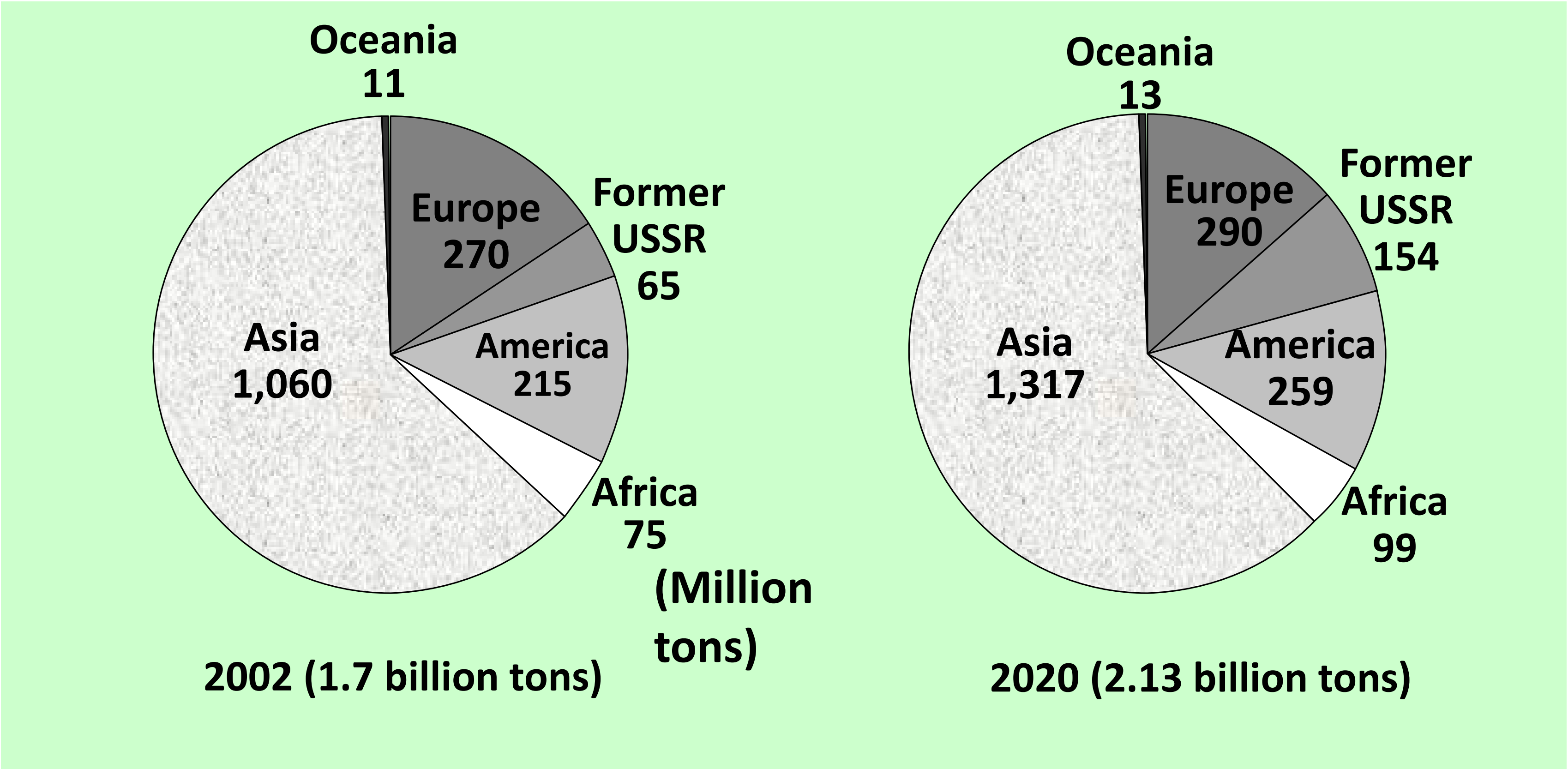
Estimated World Cement Production (by Jahren)



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The Result

- The cement in each m^3 of concrete produces about 300kg of CO_2
- About 1 tonne of concrete is produced per person per year in the UK
- That means that of our carbon footprint of 5-10 tonnes of CO_2 per year about 3% comes from concrete
- The world average is about 7% because the average total footprint is lower.

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Cement Replacements

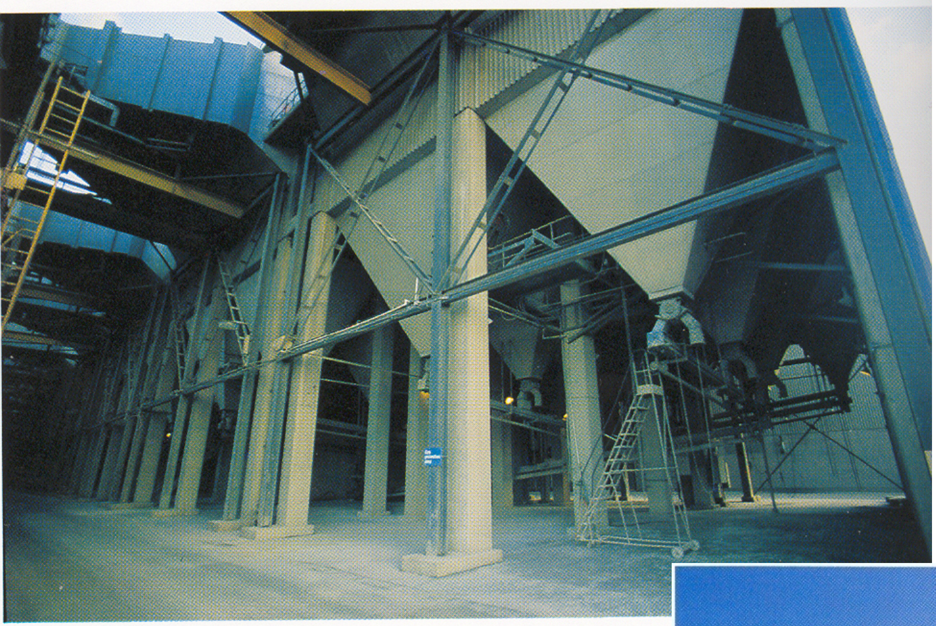
- Pulverised Fuel Ash
- Ground Granulated Blastfurnace Slag
- Condensed Silica Fume

PFA (PULVERISED FUEL ASH)

- PFA is the ash from the burning of pulverized coal in power stations.
- About 20% of the PFA fused into large particles and drops out of the flue gases to form furnace bottom ash.
- The remaining 80% (fly ash) is extracted with electrostatic precipitators and the material for use with cement is obtained from this.

The Pantheon was built with fly ash ...
but from a volcano

PFA Handling

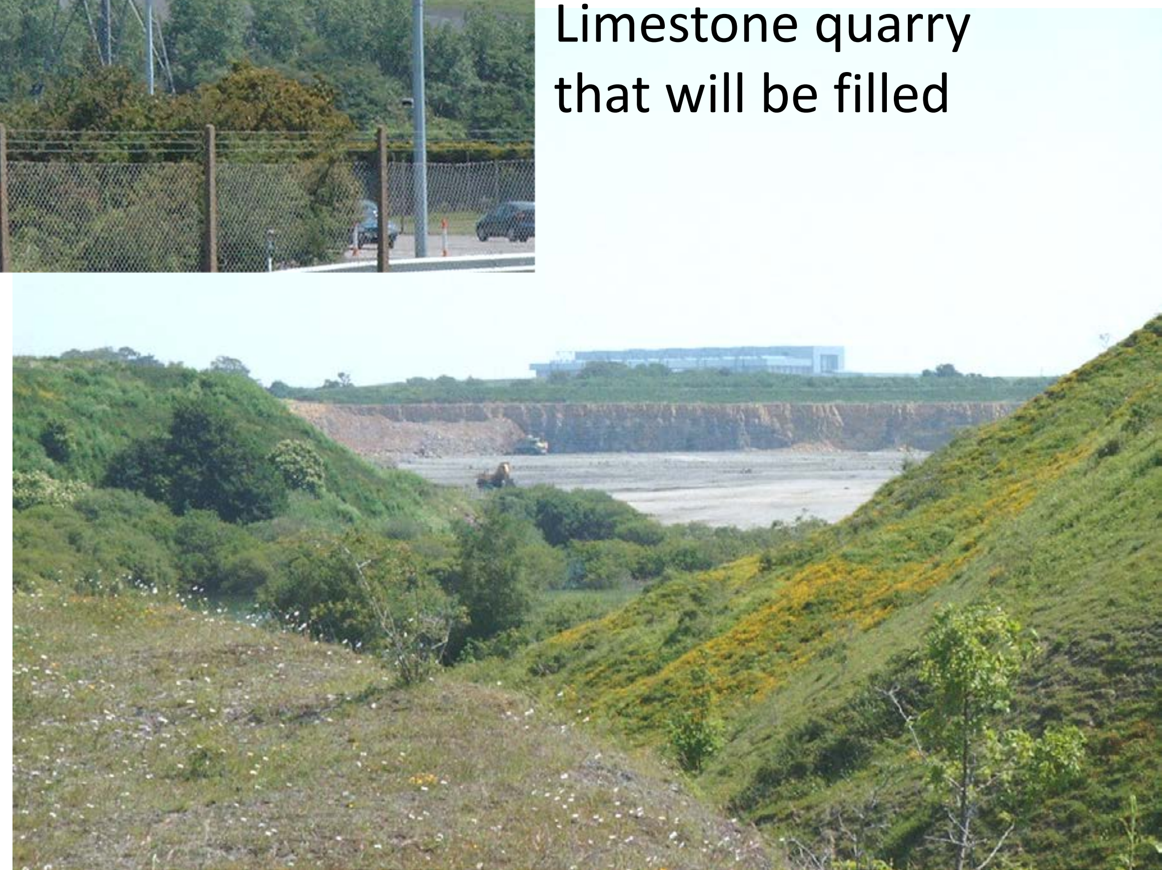


Precipitator Hopper.

PFA Dumping

Existing Dump

Limestone quarry that will be filled



Applications for fly ash…

- to Heathrow Terminal 5 to sewage treatment plants…

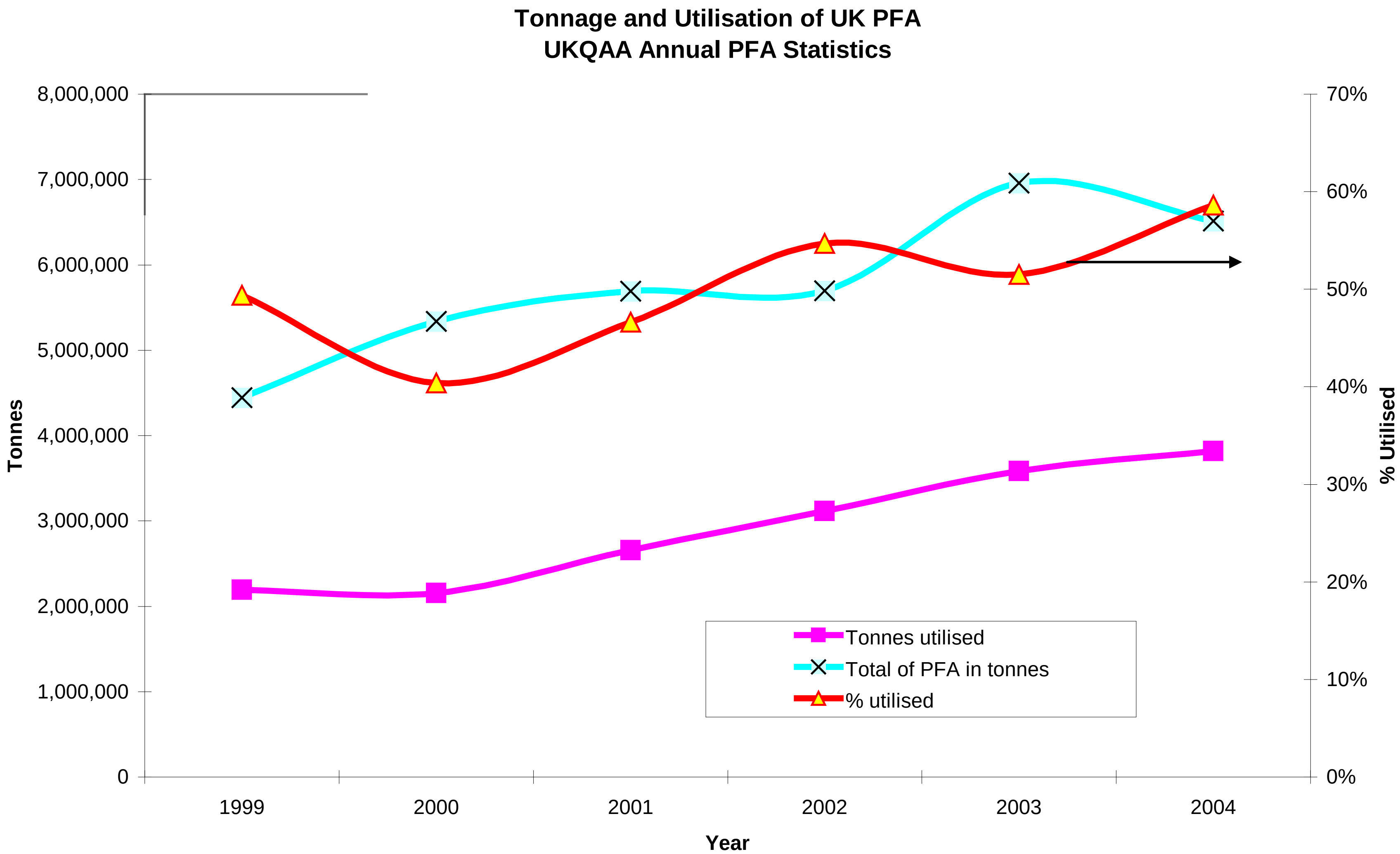
Barriers to the use of PFA…

- The classification the PFA/fly ash that it is a waste!
  - A long and complex story
  - The Environment Agency and SEPA believe PFA is a waste
  - The UKQAA/Power Industry believe that fresh PFA is NOT a waste!
  - Discussions have been ongoing for years

Emissions to the environment:

- CIA/DETR project showed that using 30% PFA for equal 28 day strength in a concrete mix that:
  - Greenhouse gas emissions are reduced by 17%
  - Acidification reduced by 15%.
  - Winter smog reduced by 15%.
  - Eutrophication reduced by 13% .
  - Primary energy requirements reduced by 14%.

PFA/fly ash utilisation on increase despite EA and waste issue …



Cement Replacements

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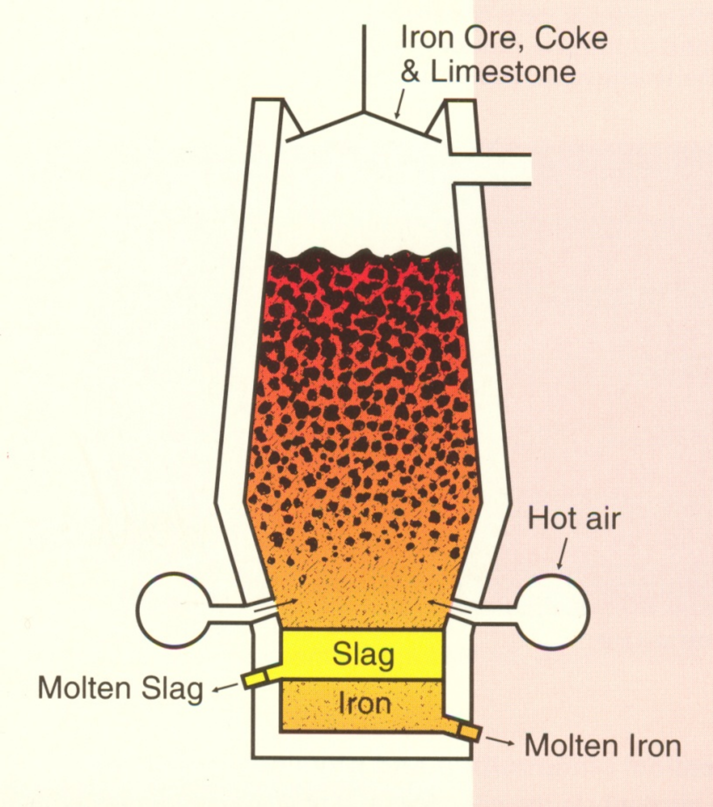
- Ground Granulated Blastfurnace Slag
- Condensed Silica Fume

GGBS (GROUND GRANULATED BLASTFURNACE SLAG)

- Slag is derived from the production of iron in blastfurnaces.
- The slag contains all of the compounds which would affect the purity of the iron.
- The slag is a hot liquid and may be cooled in air, by mixing with water (foaming) or with high pressure water jets at high water/slag ratios (granulation).
- Only granulation produces non-crystalline slag and only this slag exhibits hydraulic properties and is therefore suitable for use with cement.
- The other types of slag are used as aggregate.

Blastfurnace Slag as a Cementitious Material

- 1862 Germans realise that slag is hydraulic
- 1892 Blastfurnace cement produced in USA
- 1957 Used in UK dam construction
- 1964 Wet Sleddale Dam, Cumbria
  (within mixer blending).



Blastfurnace Slag

GGBS Project

GGBS Project

Limits to the use of GGBS

- All the GGBS produced in the UK is now used
- It costs almost as much as cement
- Some old steel works have insufficient space to install granulators.

Cement Replacements

- Pulverised Fuel Ash
- Ground Granulated Blastfurnace Slag
- Condensed Silica Fume

CSF (Condensed Silica Fume)

- This is a highly reactive pozzolan is also known as microsilica and is derived from the production of silicon steel.
- The production process is highly energy intensive and is carried out in countries like Sweden where hydropower is available.
- The high reactivity can be used to obtain very high strengths but means that great care must be taken with curing etc.
- Various problems have been reported with this material.

CSF Projects

Tsing Ma Bridge,Hong Kong. 200m high towers slipformed with microsilica concrete – specified for ease of placement and resistance to an aggressive marine environment.

Tried and Tested on the World's Most Demanding Projects

The benefits of microsilica were first recognised in the 1950s and for more than 20 years microsilica concrete has been specified around the world for the most demanding and prestigious structures.

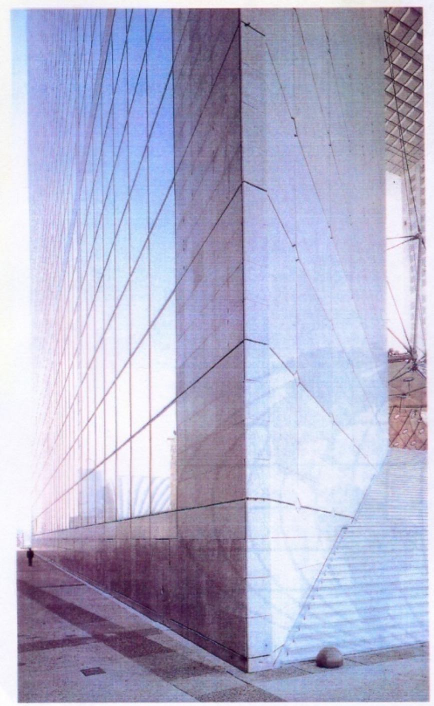
proven

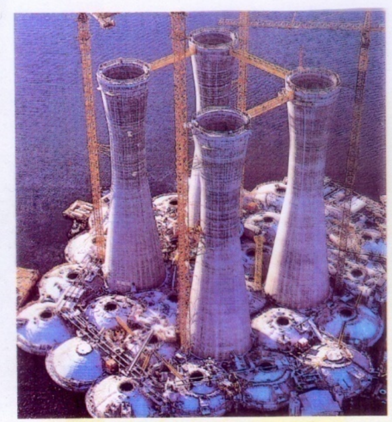
Canada, Denmark, Germany, Iceland, Norway, Sweden and the USA all have national specifications for the material.

Tarmac Topmix, ***the*** specialist ready-mixed concrete producer and Elkem, the giant of the silicon alloy industry, have pooled their resources to make Toproc available throughout the UK. Now a growing number of civil engineers are discovering the benefits of Toproc's unparalleled durability, high early build strength, speed, pumpability, long life and ease of use.

There are no uncertainties. All applications have been thoroughly researched, tested and proven in the most demanding and aggressive of environments.

La Grande Arche, Paris.
Constructing a 100m cube, 40 storeys high would not have been possible without microsilica technology.





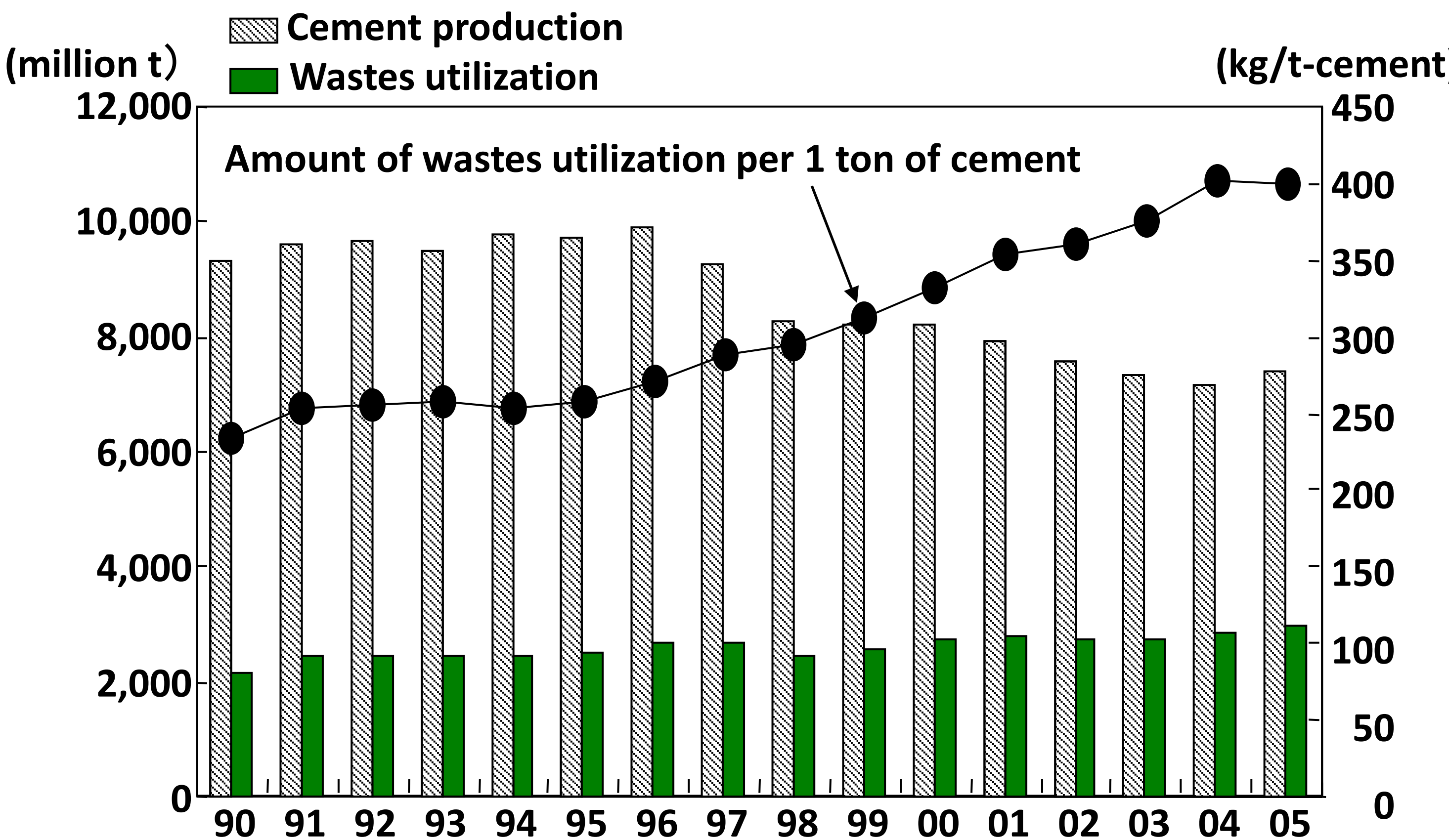
Gulfaks C Oil Platform:
The innovative construction methods used to build North Sea oil platforms developed around the beneficial pumping properties of microsilica concrete.

Relative environmental impacts for ‘C30’ concrete

[Concrete Industry Alliance Report Jan 2000]

Impact	PC-only	30% Fly ash	50% GGBS
Greenhouse gas (CO2)	100%	83%	60%
Primary Energy	100%	86%	71%
Mineral extraction	100%	96%	92%

Amount of Wastes Utilization for Cement Production in Japan



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    - Site trials
    - New research

The Six Trials

- Trials 1-3
  - concrete barriers for landfills.
  - 70 m^3 of concrete.
- Trial 4
  - trench trial for mine or trench backfill.
  - 7 m^3 of concrete.
- Trial 5
  - slab in a car park
  - 16 m^3 of semi-dry concrete
- Trial 6
  - access road
  - stabilised 72 m^3 of soil and placed 6m^3 of a semi-dry paste (grout) as a road base

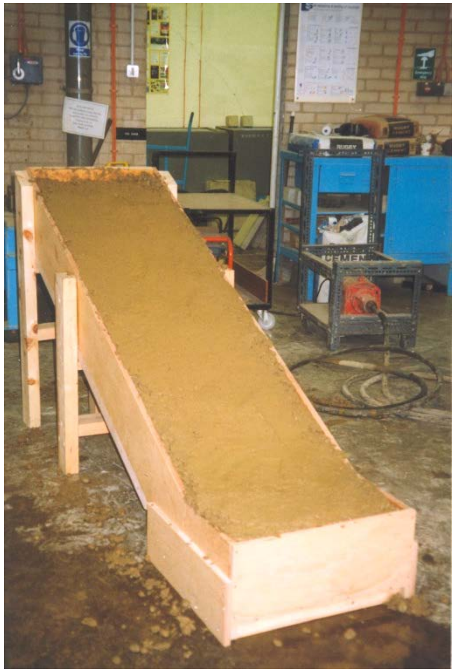
Some of the secondary materials used

- CKD Cement Kiln Dust from cement works
- BPD By-pass dust also from cement works
- Lagoon Ash from power station
- BOS Basic Oxygen Slag from steel manufacture
- Red Gypsum from titanium dioxide (white pigment) production
- PB Waste Plasterboard (gypsum)
- Sodium sulphate solution from lead-acid battery recycling
- Spent borax from silver refining

The mixture designs for the trials

Trial	Pour	Cementitious component	Strength MPa
1	Cell 1 top	Spent borax 100%	4.5
2	Cell 2 top	CKD 60%, Lagoon ash 40%	1.7
3	Cell 3 top	CKD 60%, Lagoon ash 40%	1.3
1	Cell 1 base	GGBS 90%,OPC 10%, Sodium sulphate	13
2	Cell 2 base	CKD 60%, PFA 40%, Sodium sulphate	6.9
3	Cell 3 base	OPC 5%, CKD, 70%, Lagoon ash 25%	6
4	Trench fill	BOS 60%, Red Gypsum 40%	1.8
5	Sub-base	BOS 80%, PB 15%, BPD 5%	10.8
6	Base course	BOS 80%, PB 15%, BPD 5%	30.55

Lab testing for Trials 1-3



Secondary materials in the mixes

Trial 4 – Gypsum/slagTrench Trial

Placing Trial 4.

Where we want to put the gypsum/slag blend (10 M m^3)

The “Coventry Blend”

- Basic oxygen slag from steel manufacture (80%)
- Waste plasterboard (15%)
- Kiln by-pass dust from cement manufacture.(5%)

100 Tonnes of this blend were made for trials 5 and 6

This blend is not recommended for partial replacement of cement – it is for use without cement

Trial 5
Car Park

Trial 6
Semi-Dry
Paste/grout

Concrete without Cement (Trials 5 and 6)

Concrete (trial 5)

Semi-dry paste/grout

(trial 6)

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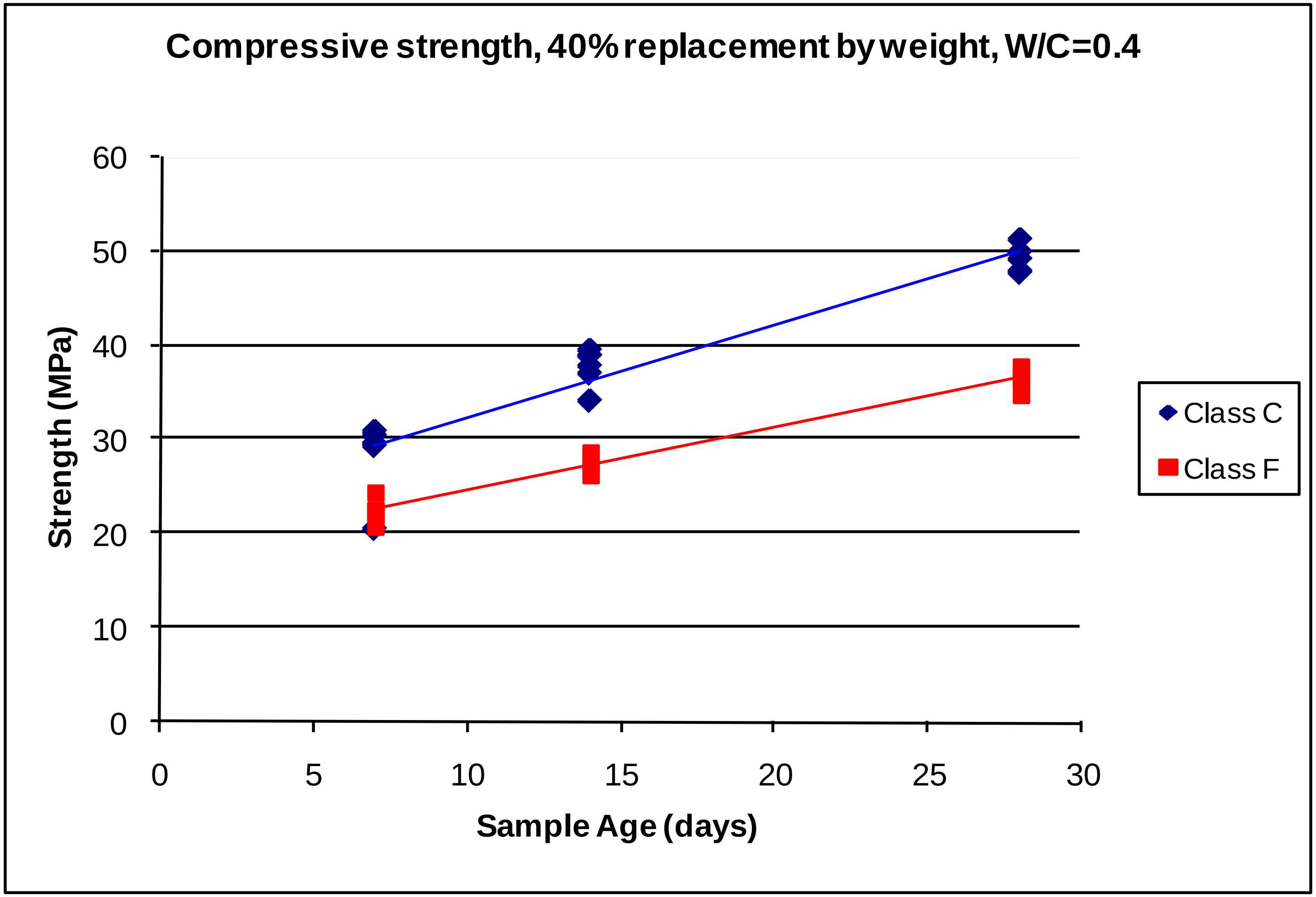
New research

- Site trials we are trying to promote
  - Subway backfill with high-lime PFA
  - Block trial with gypsum mix
- Trials with incinerator ash
- Combinations of slags
- High-lime PFA

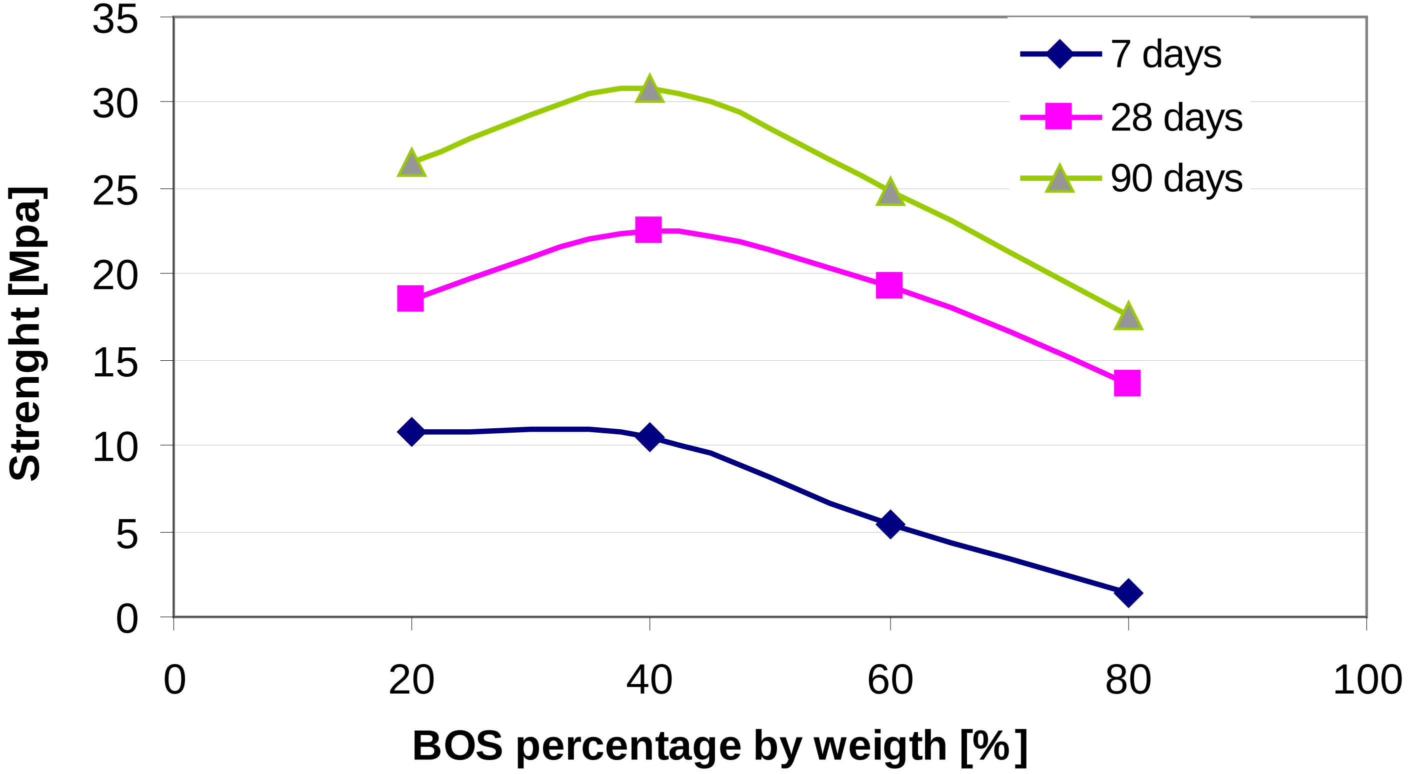
Initial results with fly ash from the Coventry domestic waste incinerator

Mix	W/C	Incinerator fly ash	Cement by-pass dust	Lime from sugar processing	OPC	7 d strength	28 d strength
1	0.5	60		40	0	soft	soft
2	0.5	50		50	0	soft	soft
3	0.5	70		30	0	0.11	0.14
4	0.5	40		60	0	6.4617	12.69
5	0.5	60		10	30	3.52	5.53
6	0.5	0		0	100	5.67	26.52
7	0.5	80	20		0	4.78	3.91
8	0.5	60	40		0	2.06	3.15
9	0.5	50	50		0	1.64	1.53
10	0.5	70	30		0	3.25	4.24
11	0.5	60	10		30	2.88	2.88
12	0.4	40	30		30	2.54	1.88
13	0.4	70	0		30	1.02	3.78

High-Lime PFA from burning Indonesian coal at Rugeley

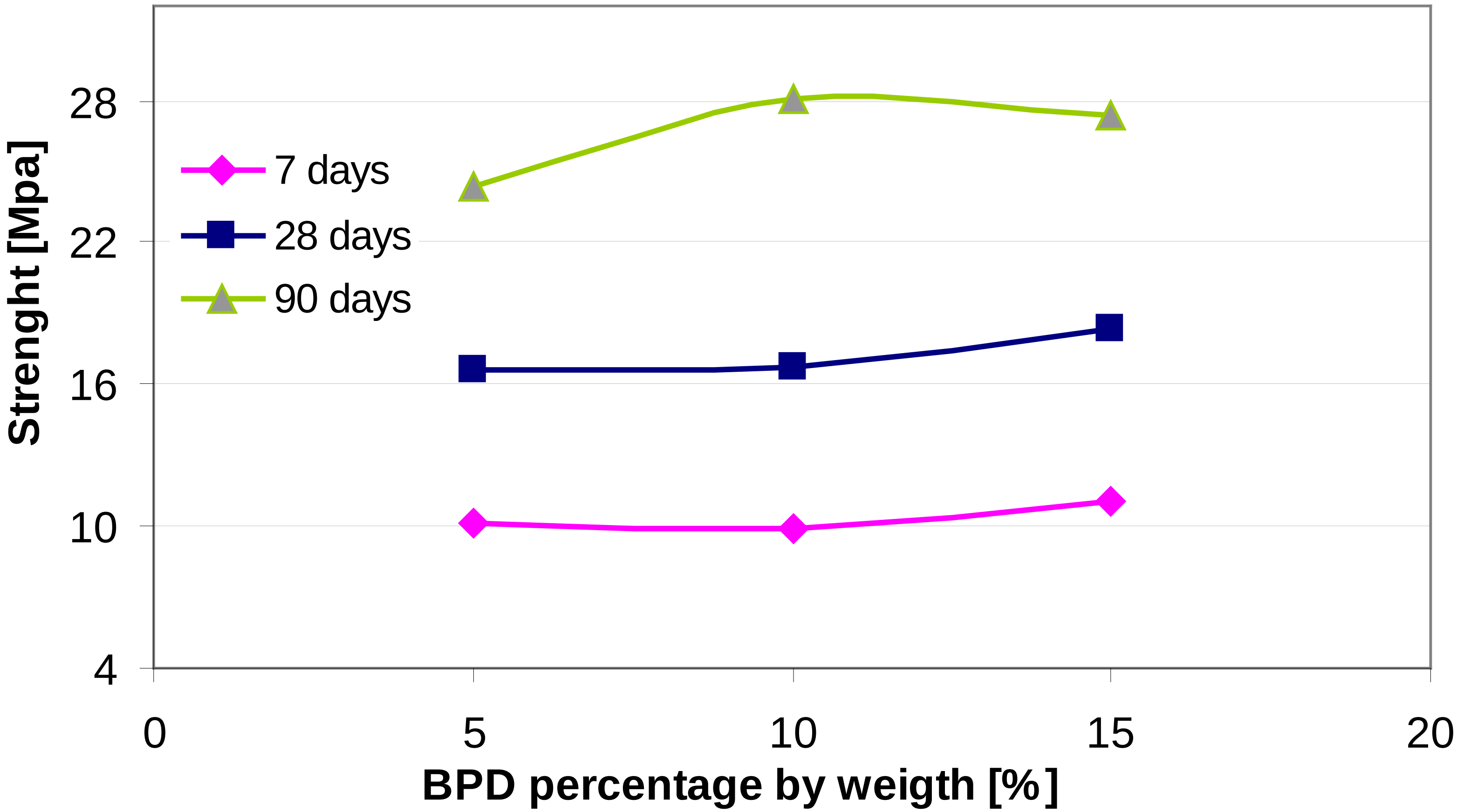


Compressive strength of BOS-GGBS

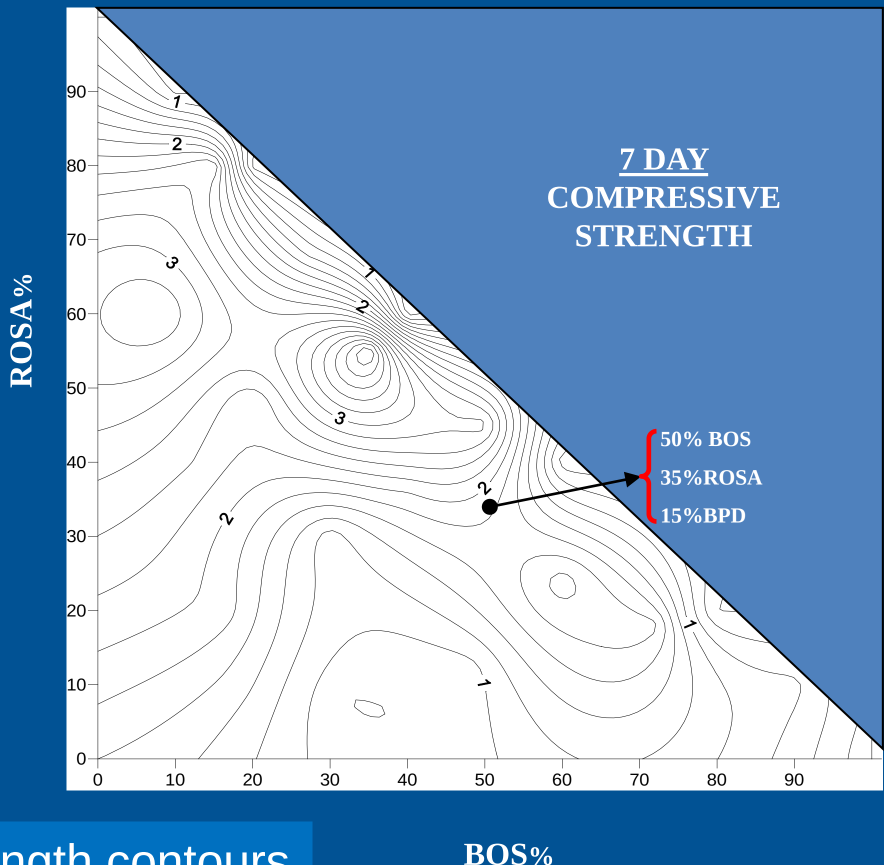


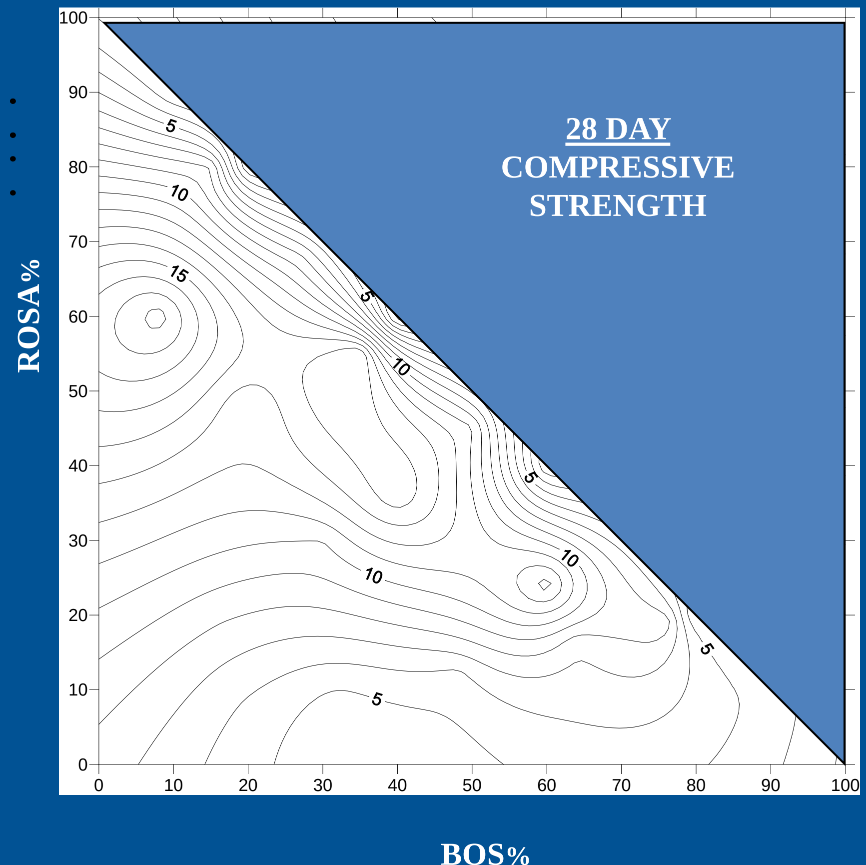
Compressive strength of BPD – GGBS – BOS

40% BOS and 60% GGBS



BOS + ROSA +BPD Compressive strength MPa





Strength contours for mixes with no cement

ROSA = Run of Station Ash (Coal fired power plant) BPD = By-pass dust (Cement works)

PG = Plasterboard (wall board) gypsum BOS = Basic Oxygen Slag (Steel works)

RG = Red Gypsum (Titanium dioxide pigment plant)

Other tests carried out or in progress

Rheology – viscosity and yield point

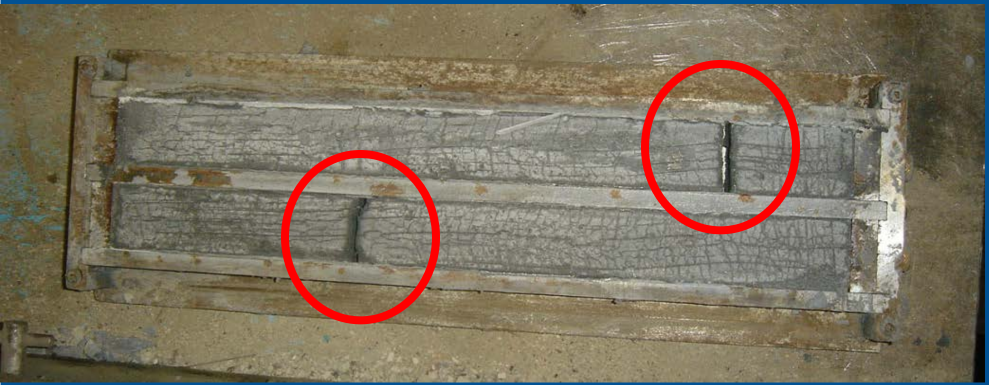
Freeze-thaw

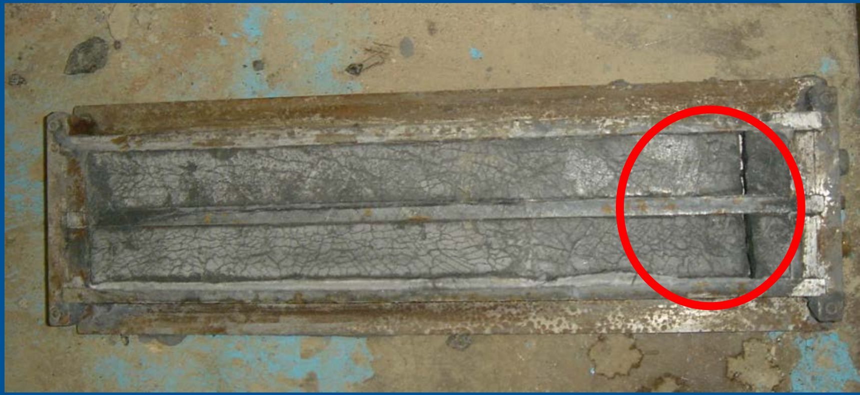
Permeability (picture below)

Diffusion (picture below)

Sample Expansion

BOS+BPD+PG+30%L/S





BOS+ROSA+RG+27%L/S

BOS+ROSA+RG+25%L/S

CONCLUSIONS 1

- Viable mixtures which contain little or no Portland cement can be made for a wide variety of applications.
- Site trials represent the best route to develop these mixtures for commercial use.
- Pre-blended mixtures are the best way to use powder which contains several mineral wastes.

Conclusions 2

- While it is possible to demonstrate the viability of cementitious mixtures which are sustainable there are many difficulties which may prevent their industrial use. These include:
  - Insurance problems
  - Lack of capital investment
  - Environmental concerns which may or may not have any scientific basis

Thank you

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