SECOND INTERNATIONAL
SLAG VALORISATION SYMPOSIUM
THE TRANSITION TO SUSTAINABLE MATERIALS MANAGEMENT

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Production of sintered lightweight aggregate using waste ash and other industrial residues

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HT centre

SMART-PRO²

Presentation Outline

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Drivers for change and resource efficiency

Overview on residues from thermal processes

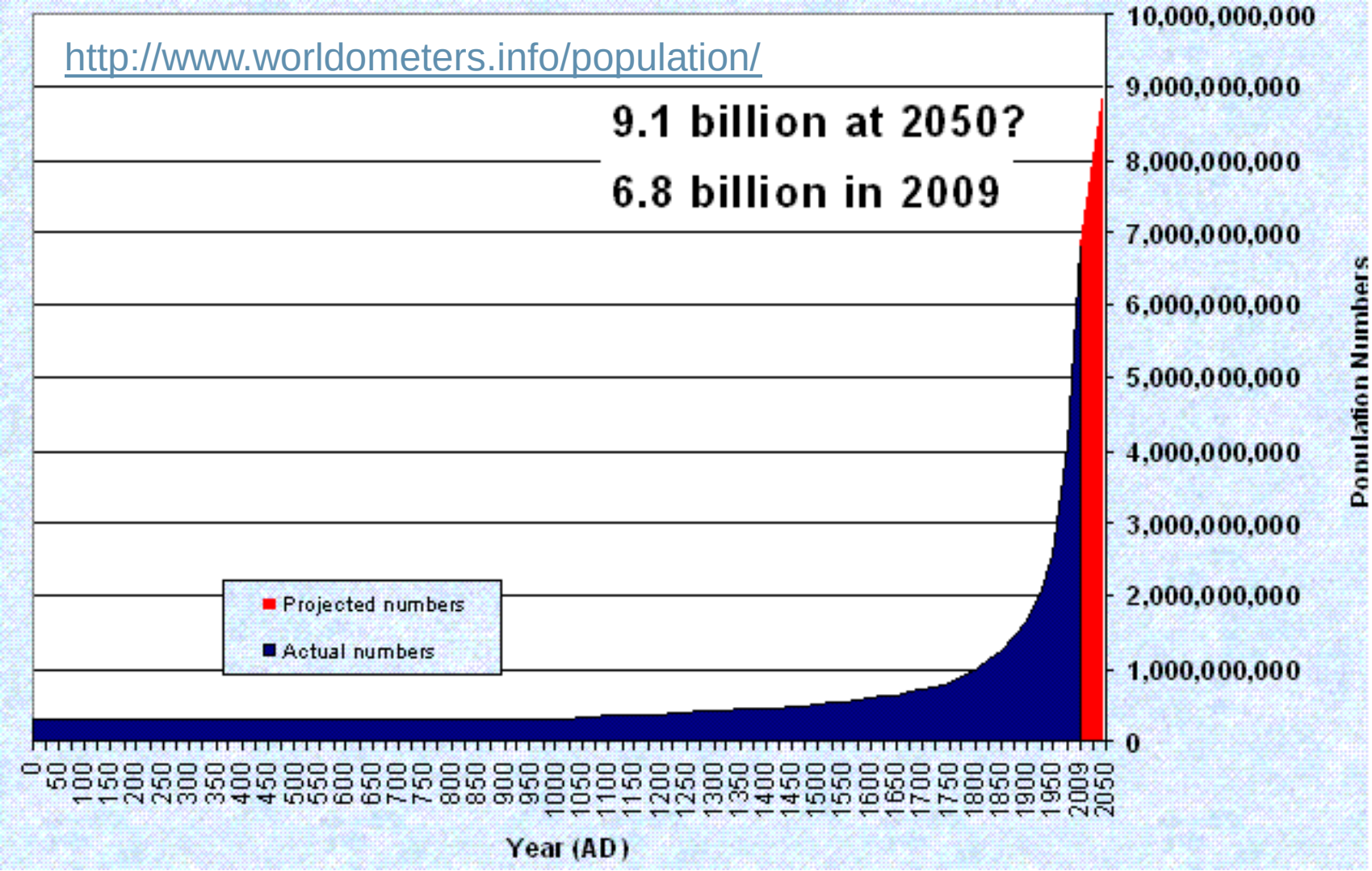
Lightweight aggregate

Lytag manufactured from PFA, and why it is not ideal

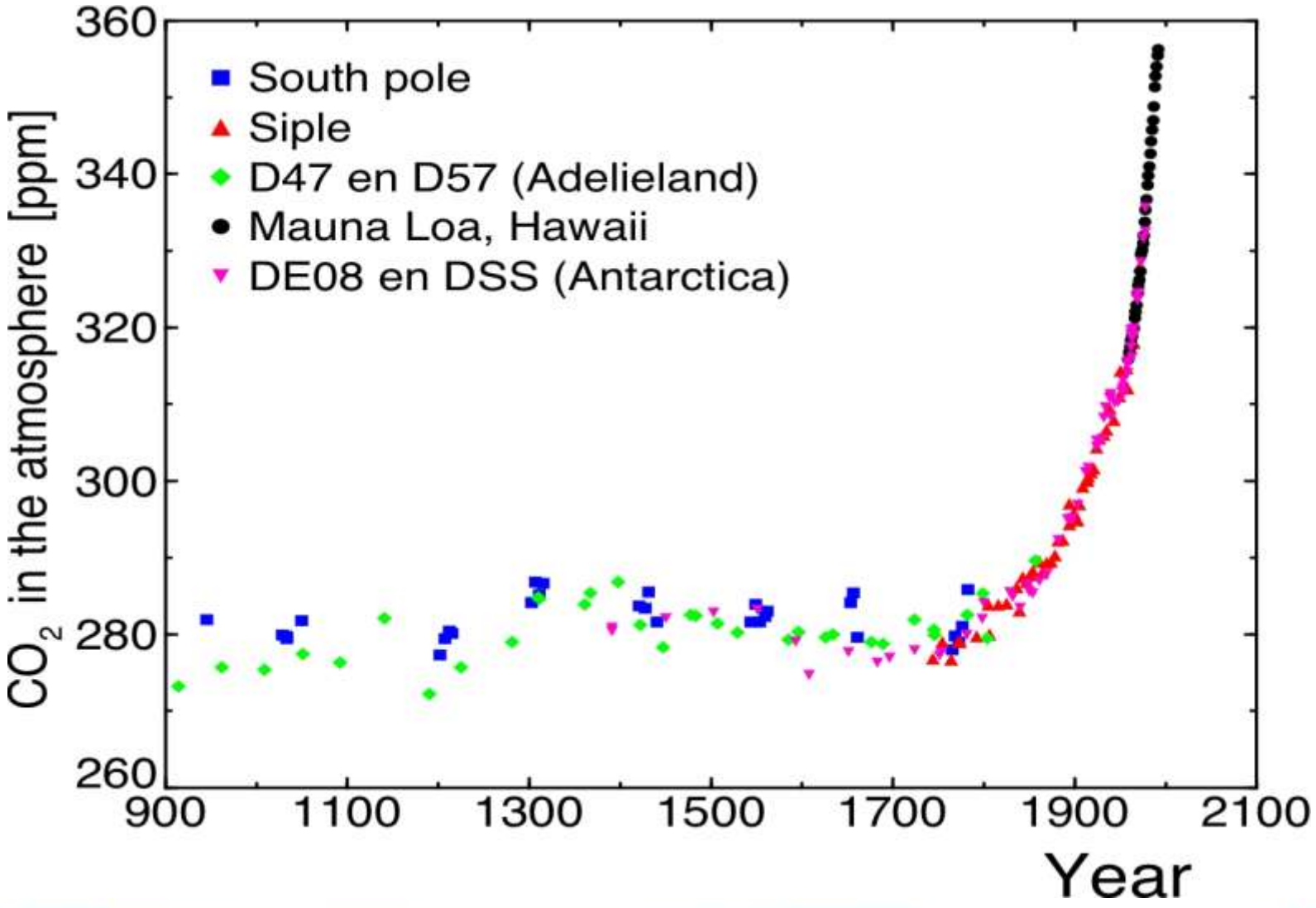
Examples of research: incinerator bottom ash and sewage sludge ash

Conclusions

World population growth



CO_2 in the atmosphere



Drivers for change

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Environmental issues

- CO_2 emissions
- Climate change
- Population growth
- Exploitation of natural resources

Government Initiatives (EU and UK)

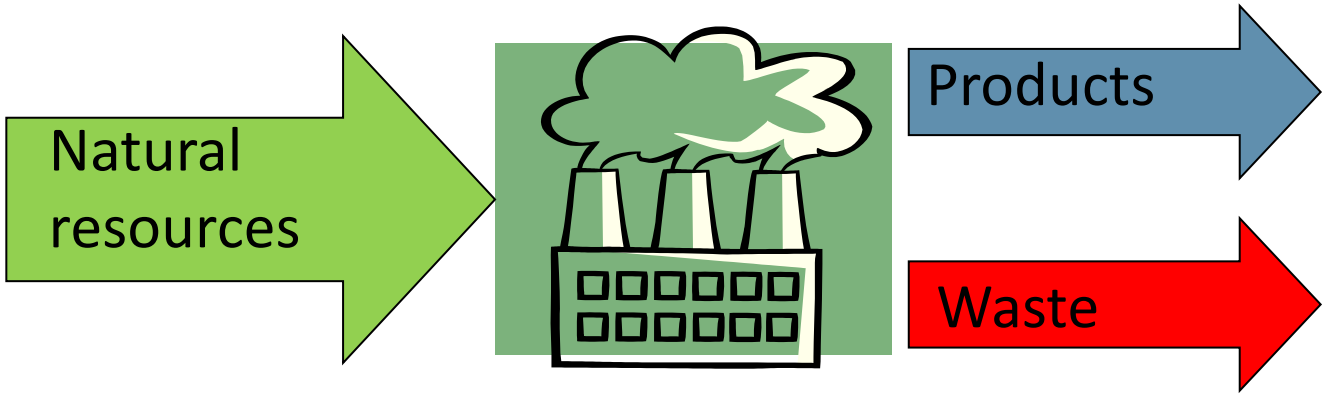
- Increased cost of energy/transport
- Waste disposal tax
- CO_2 pricing
- Taxes on resource extraction

Business Development and Innovation

- Industrial symbiosis
- Resource efficiency
- Sustainable materials
- Low-carbon economy

Mid 20th century industry

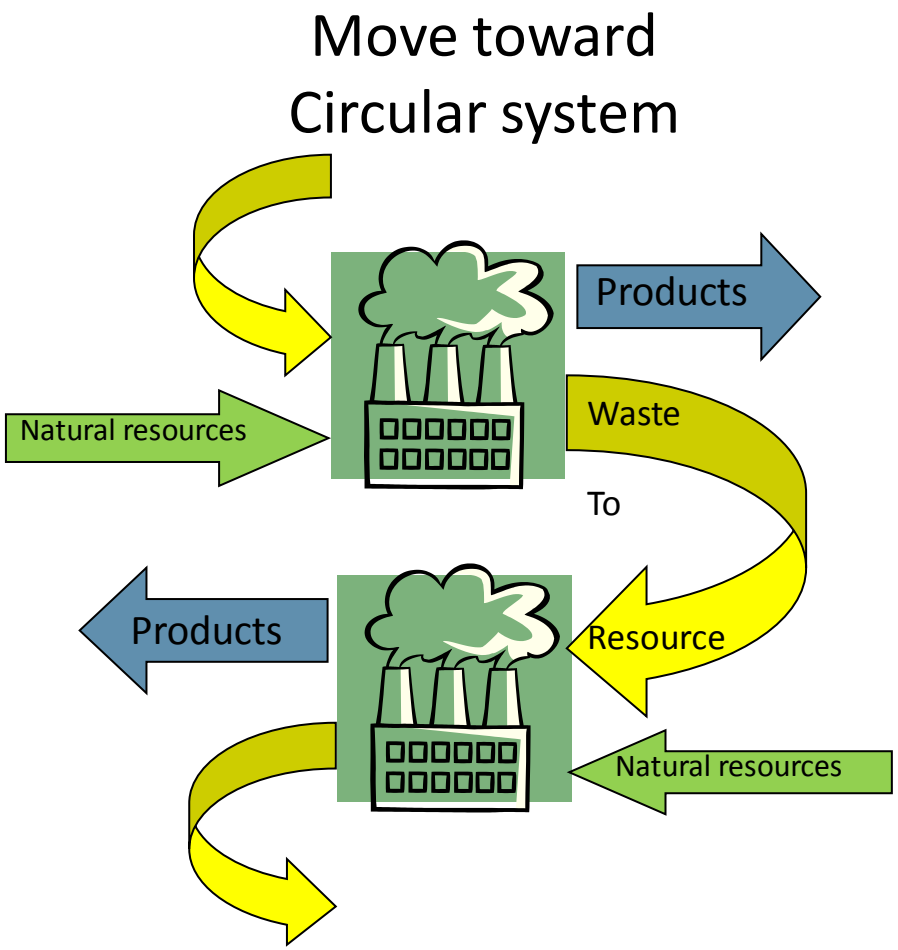
Linear system



Courtesy of Peter Laybourn, NISP

Conventional primary raw materials

Industrial symbiosis



Courtesy of Peter Laybourn, NISP

Wastes as important new resources

Materials flow for resource efficiency

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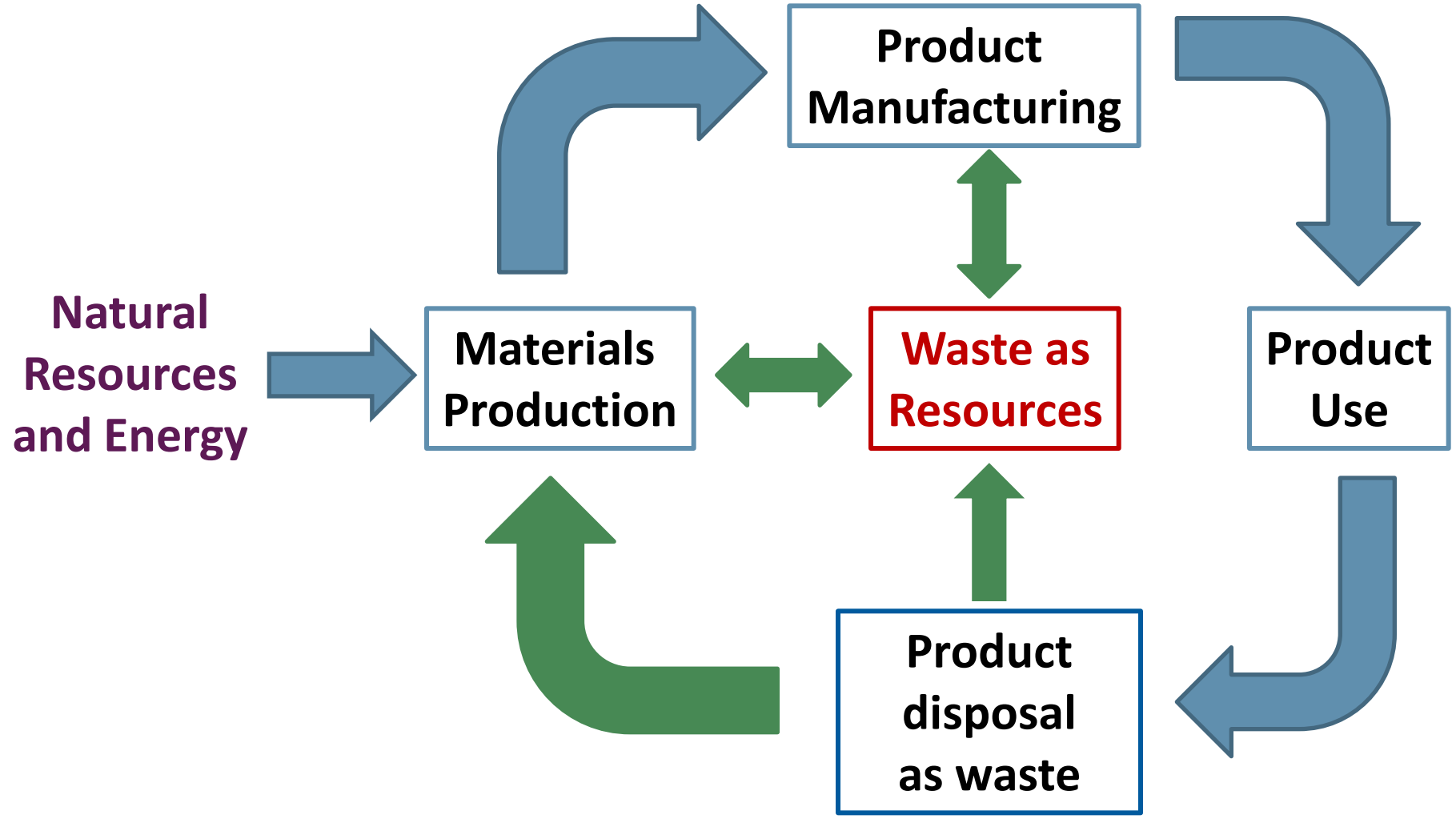

Residues from thermal processes

Residues from thermal treatment processes

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Coal power stations:	**Pulverised fuel ash (PFA)/fly ash** **Furnace bottom ash (FBA)** **Flue gas desulphurisation (FGD) waste**
Energy from waste:	**Incinerator bottom ash (IBA)** **Air pollution control (APC) residues**
Biomass ash:	**Incinerated sewage sludge ash (ISSA)** **Paper sludge ash (PSA)** **Wood and other biofuel ashes**
Steel industry:	**Ground granulated blast furnace slag (GGBS)** **Electric arc furnace (EAF) dust**

General characteristics and issues for reuse

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Glassy and/or crystalline, similar to volcanic ashes

Aluminosilicate based, with residual carbon content and other contaminants

Pozzolanic - potential for use as cement replacement materials

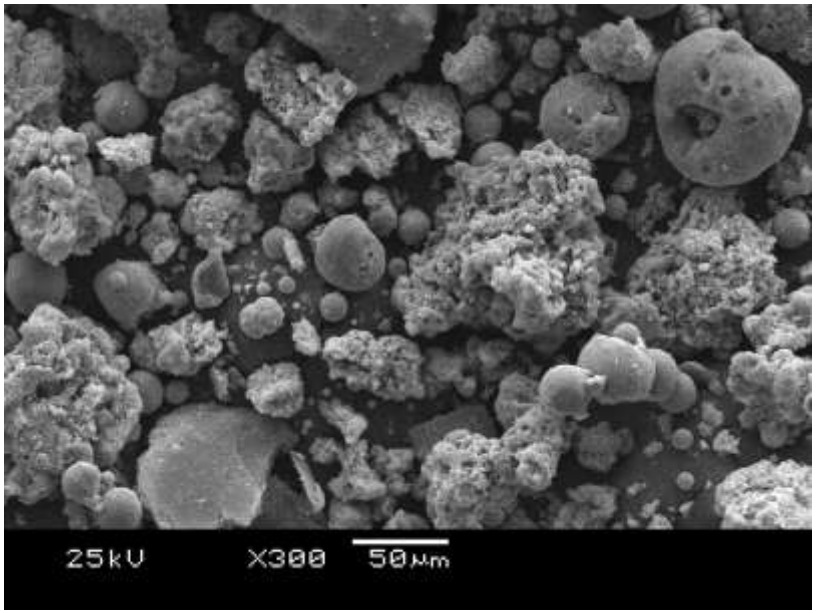
Variable - waste residue, development of beneficiation processes

Relatively low volumes in many cases

Some may have fertiliser value

May be hazardous wastes

Concern over leaching into the environment



ISCOWA - The International Society for the Environmental and Technical Implications of Construction with Alternative Materials

http://www.iscowa.org/

Technologies/materials processing

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Cement and concrete

Geopolymers

Alkali-activated pozzolans

Reuse by carbonation technologies

Liquid phase sintering - ceramics/glass-ceramics

Inorganic-organic composites

Lightweight aggregate for structural lightweight concrete

Lightweight aggregate

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- Granular material, typically 6-10mm diameter
- Low density, ideally ~ 1.1-1.3 g/cm^3 but not < 1.0 g/cm^3

  (normal aggregate ~ 2.6 g/cm^3)
- Very low water absorption, ideally 0 wt.% but < 3 wt.%
- High strength
- Roughly spherical
- Surface engineered to bond into concrete

Lightweight aggregate

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Lightweight aggregate

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1. Natural materials

Pumice, volcanic slags, expanded vermiculite

2. Manufactured lightweight aggregate

Expanded clay, shale or slate:
Optiroc, Liapor, Perlite, Maxit - geotechnical uses

Recycled glass: **Poraver - lightweight thermally insulating products**

Sintered ash: **Lytag - market leader for structural concrete**

Lightweight aggregate applications

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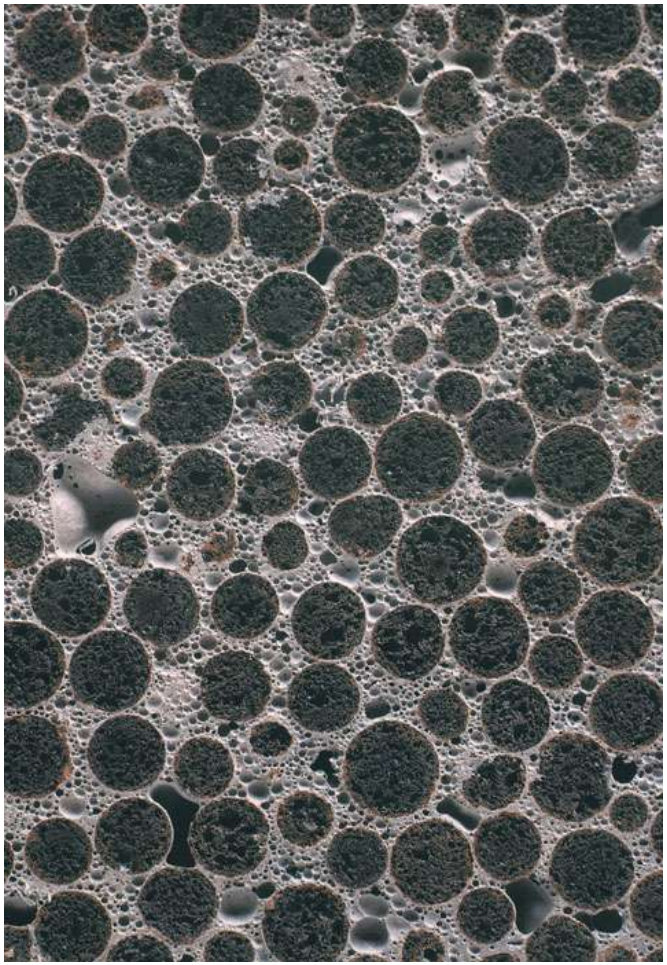
Lightweight precast concrete products
Off-site manufacturing
Structural lightweight concrete

- Lightweight fill material
- Medium for water filtration
- Landscaping and drainage
- Agricultural and horticultural applications



Lightweight aggregate manufactured from pulverised fuel ash

Lytag

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One of the most successful ash derived construction products

Uses pulverised fuel ash from coal fired power stations

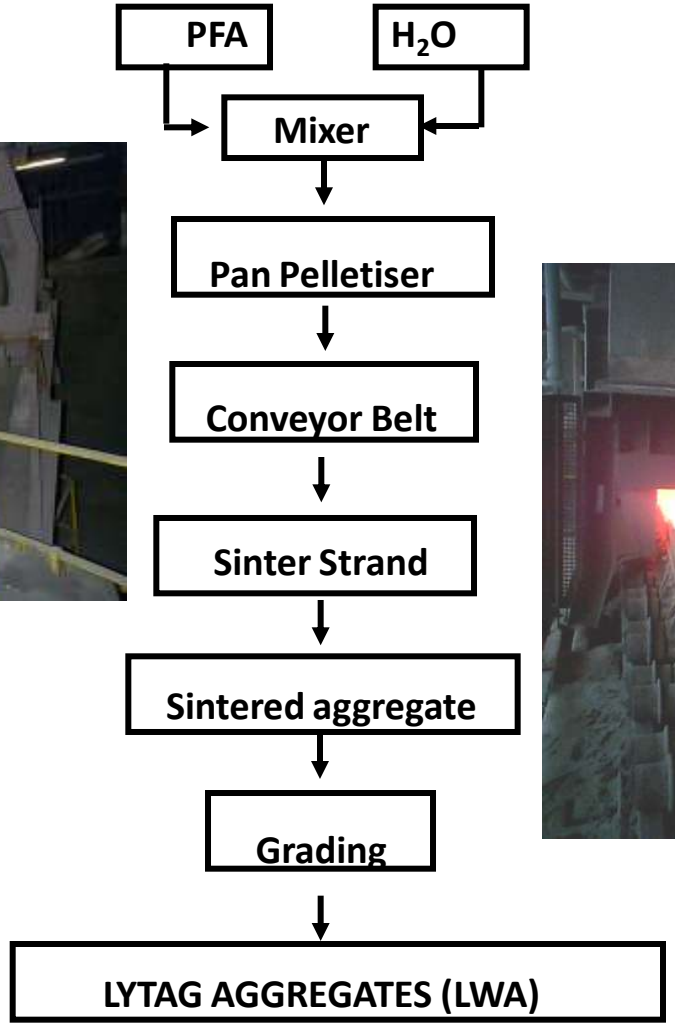
Relatively simple production process involving pan pelletising and sintering

Low-energy as uses residual carbon in ash as fuel

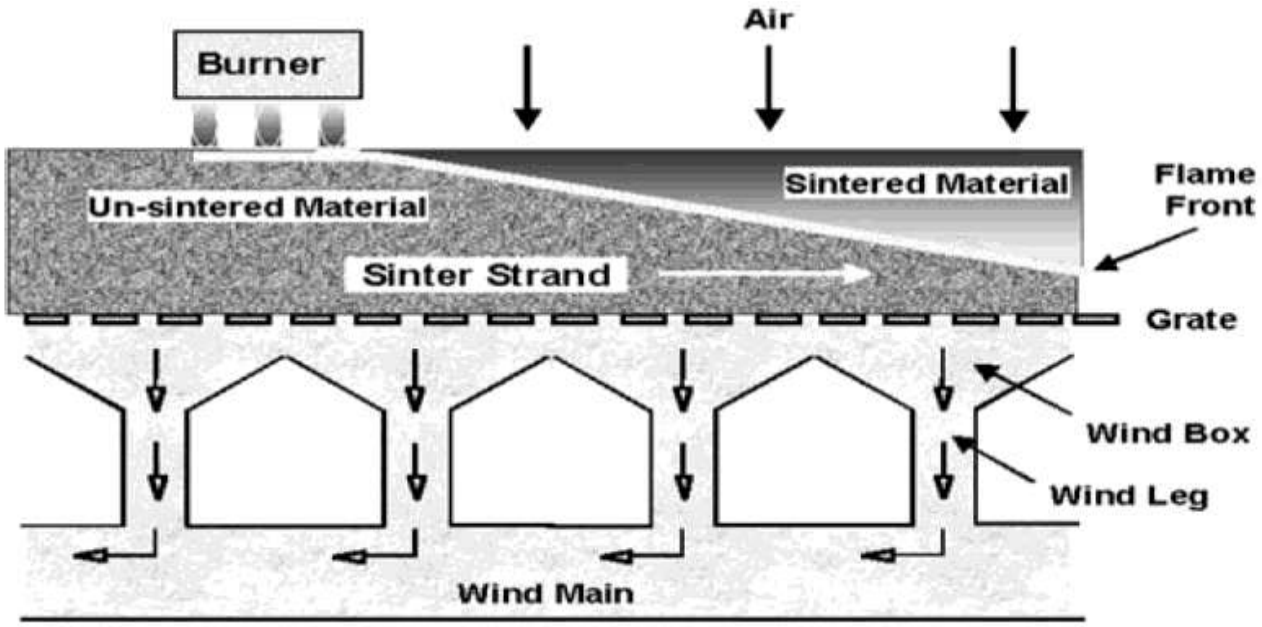
Lytag manufacturing process

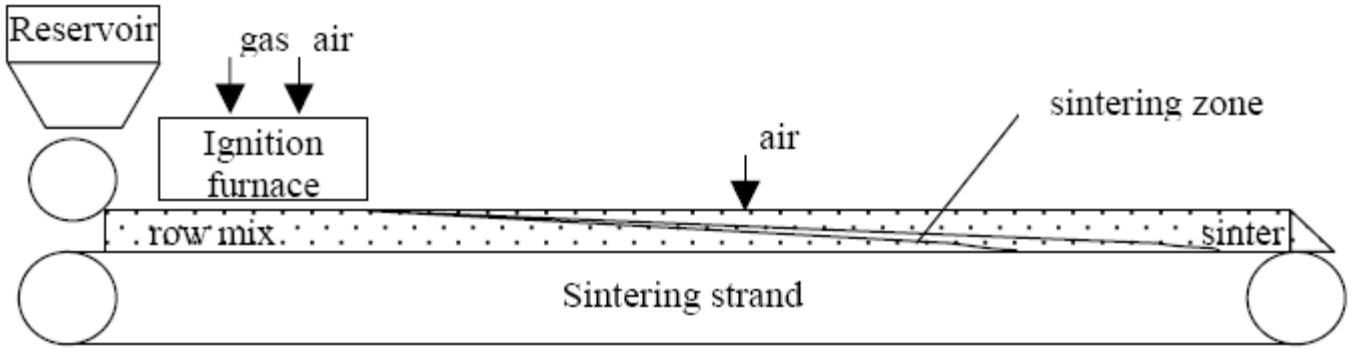
Pan pelletiser

Sinter strand



Schematic of a sinter strand





Sinter strand

Effect of rapid and slow sintering

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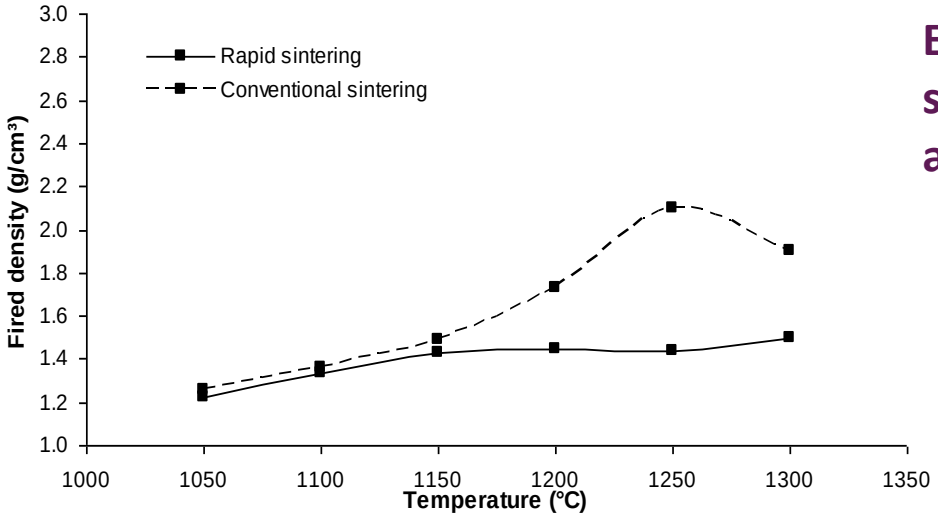
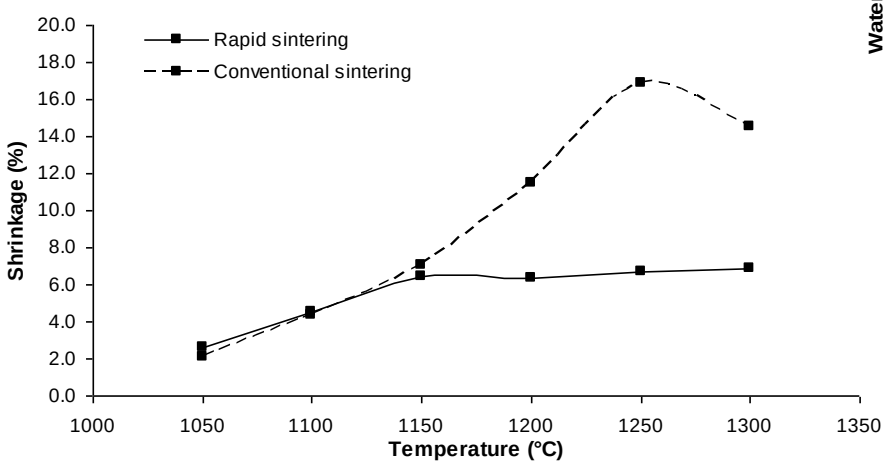
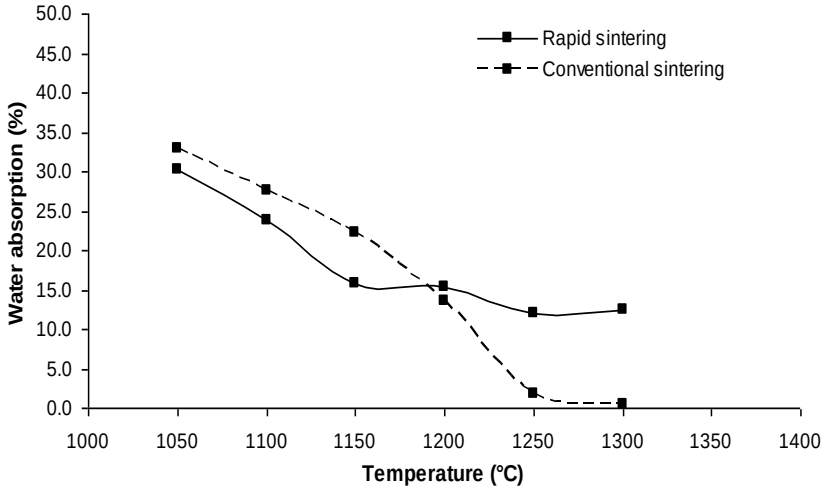
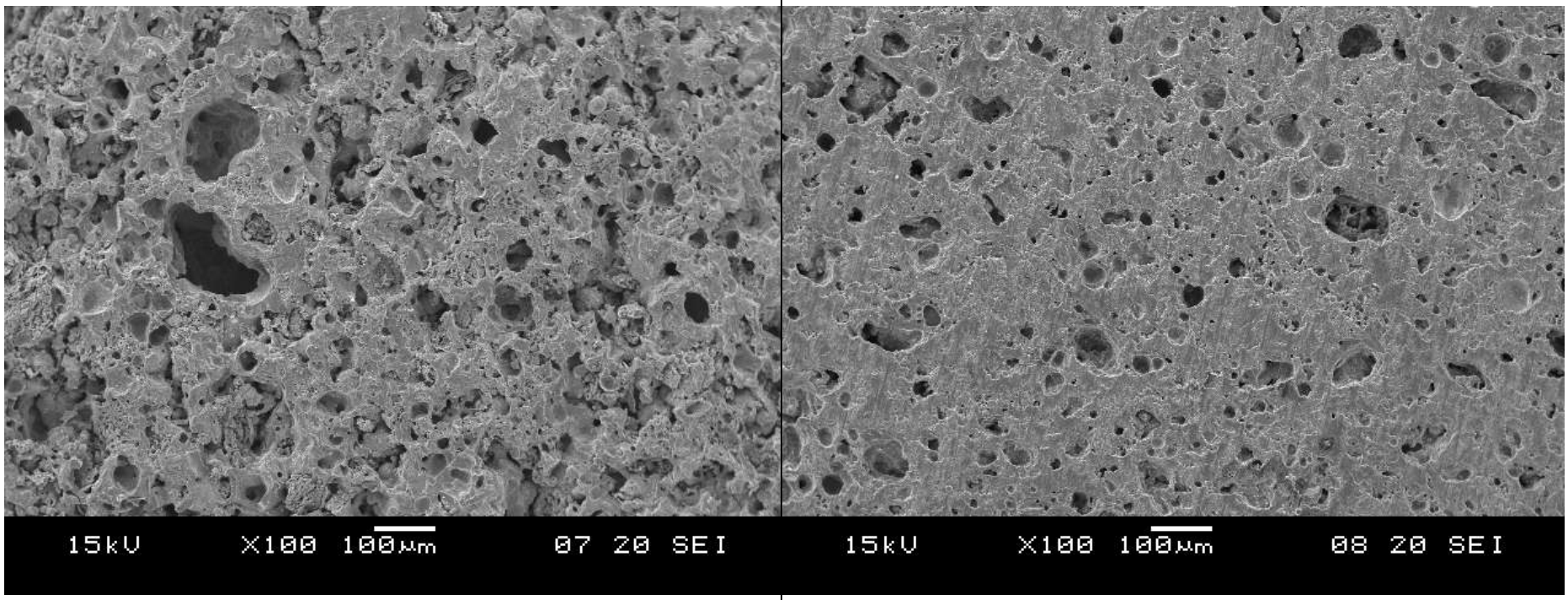




Effect of temperature on the fired density, shrinkage and water adsorption of rapid and slow sintered PFA pellets



Microstructure of sintered PFA



Rapid sintered 1250°C

Slow sintered 1250°C

Lightweight aggregate using incinerator bottom ash from energy from waste (EfW) plants

Number of EfW plants in Europe

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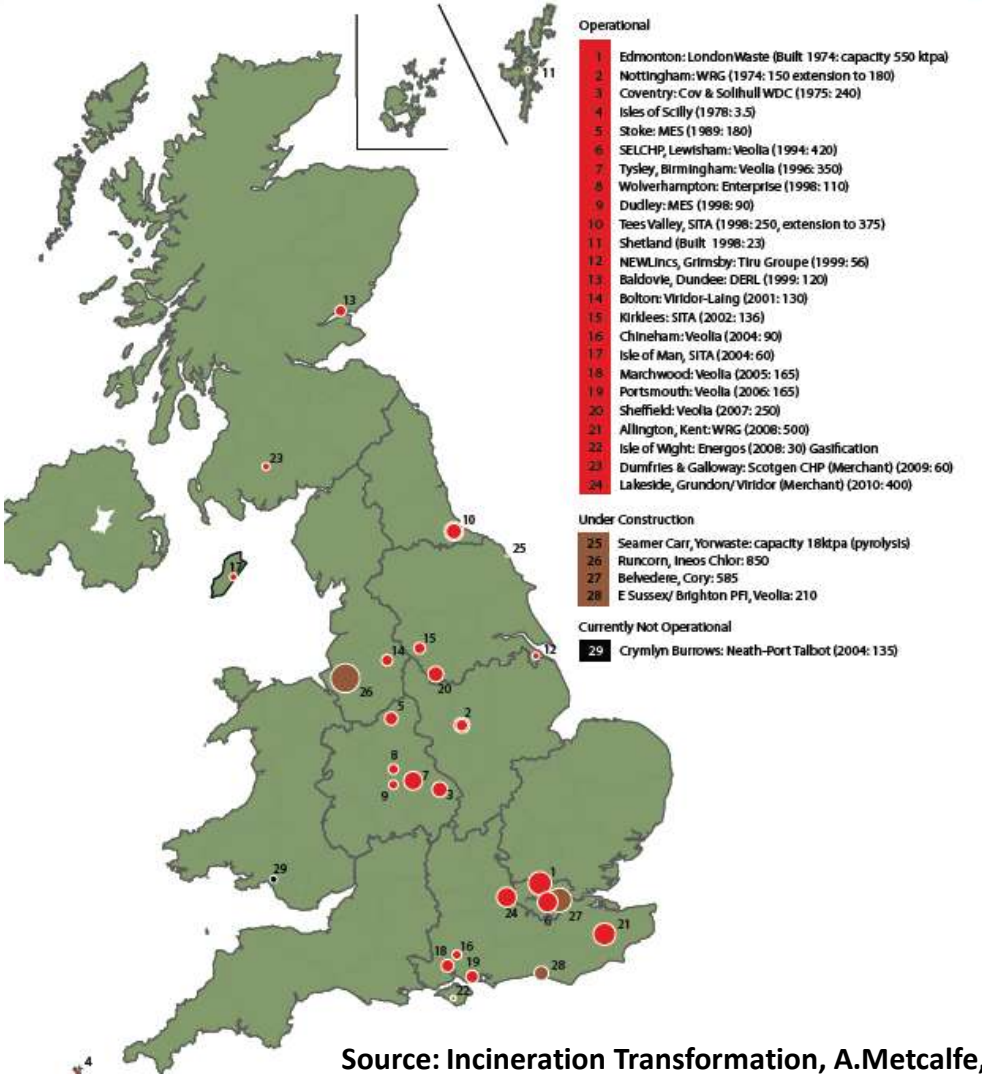
	Number of facilities	MSW Treated Mt per year
France	130	12.3
Germany	67	17.8
Italy	51	4.0
Sweden	30	4.5
Switzerland	29	3.6
UK	24	4.4
Norway	20	0.8
Belgium	16	2.6
Netherlands	11	5.8
Spain	10	1.8
Austria	8	1.6
Portugal	3	1.0
Finland	1	0.05
Poland	1	0.05

MSW
Municipal solid waste

Examples of UK EfW plants

UK Energy from waste (EfW) plants



Source: Incineration Transformation, A.Metcalfe, CIWM, June 2010

New proposed EfW facilities

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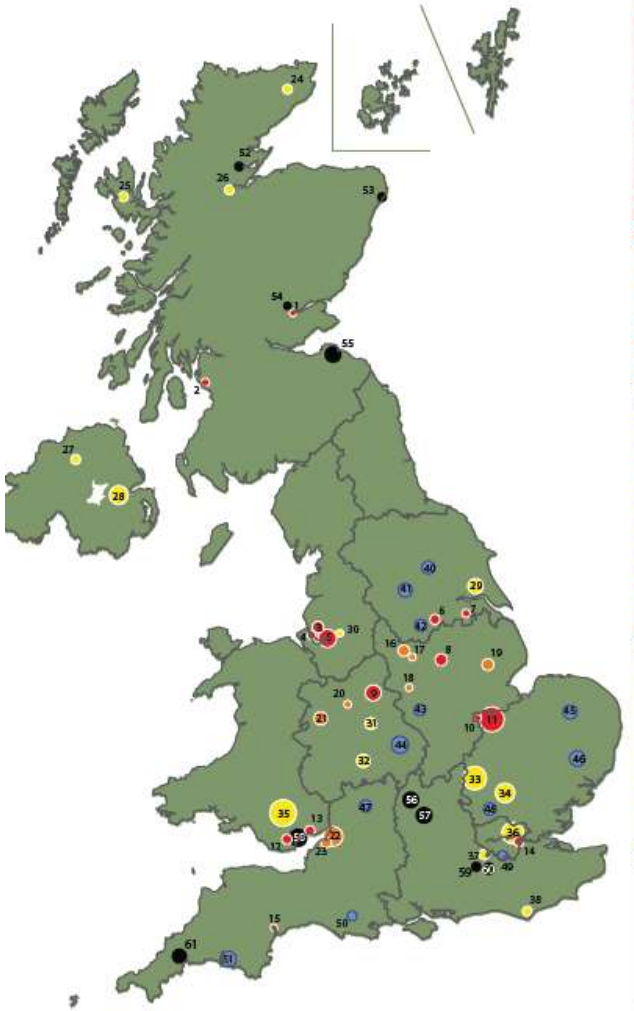
Source: Incineration Transformation, A.Metcalfe, CIWM, June 2010



Planning Permission Granted

1. SITA, Perth (Mer) (Capacity 60ktpa)
2. BioGen N Ayrshire (Mer G) (80ktpa)
3. European Metals Recycling, Bootle (Mer) (137.5)
4. BioGen Knowsley (Mer G) (95)
5. New Earth Energy/ Biossence, Mersey Green Solutions (Mer G) (400)
6. BioGen, Doncaster (Mer G) (120)
7. Singleton Birch, N. Lincs (Mer) (80)
8. Nottinghamshire, Veolia (PFI) (180)
9. Staffordshire (PFI) (300)
10. Peterborough (65)
11. PREL, Peterborough (Mer G) (650)
12. Sterecycle, Cardiff (Mer) (124)
13. BioGen Newport (Mer G) (120)
14. Biossence, Dagenham (Mer G) (100)
15. Viridor: Exeter (Municipal) (60)

Planning application submitted, no decision

16. Derbs, United Utilities (PPP G) (140)
17. Cyclamax, Chesterfield (Mer G) (60)
18. Cyclamax, Derby (Mer G) (60)
19. Lincolnshire (Mun) (150)
20. SITA, Telford and Wrekin (Mer) (62)
21. Shropshire, Veolia (PFI) (190)
22. SITA, Avonmouth (Mer) (400)
23. Cyclamax, Avonmouth (Mer G) (120)

In planning

24. Caithness: Highland 1 (Mun)
25. Skye: Highland 2 (Mun)
26. Inverness: Highland 3 (Mun)
27. Derry etc., NWRWMG (Mun)
28. Belfast etc., Arc21 (Mun) (370)
29. Hull & E Yorks/WRG (PFI) (250)
30. Warrington (Mun) (60)
31. Sandwell (Mun G) (138)
32. Hereford & Worcs, Mercia Waste (PFI) (19
33. Covanta for Bucks (PFI) (585)
34. Biffa, Herts (Mer) (400)
35. Covanta, Merthyr Tydfil (Mer) (750)
36. British Airways for biofuel (Mer G) (500)
37. Surrey Waste-SITA, Sharpness (PFI G) (60
38. Biossence, East Sussex (Mer G) (95)

PFI Reference Case

40. York/ N Yorks
41. Leeds
42. Barnsley, Doncaster, Rotherham
43. Leicestershire
44. Coventry, Solihull, Warwick
45. Norfolk
46. Suffolk
47. Gloucestershire
48. Hertfordshire
49. South London
50. Dorset
51. Devon, Plymouth, Torbay

Planning Application Rejected/Withdrawn

52. Combined Power and Heat, (Mer)
53. Buchan CHP, Peterhead (Mer) (100)
54. Grundon, Perth (Mer)
55. Viridor Oxwellmains, Dunbar (Mun)
56. WRG for Oxfordshire (PPP)
57. Viridor for Oxfordshire (PPP)
58. Viridor, Cardiff (Mer)
59. Surrey Waste-SITA, Capel (PFI)
60. Surrey Waste-SITA, Trumps Farm (PFI)
61. Cornwall-SITA (PFI)

Municipal Solid Waste as fuel

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Combustion at 900 to 1000°C

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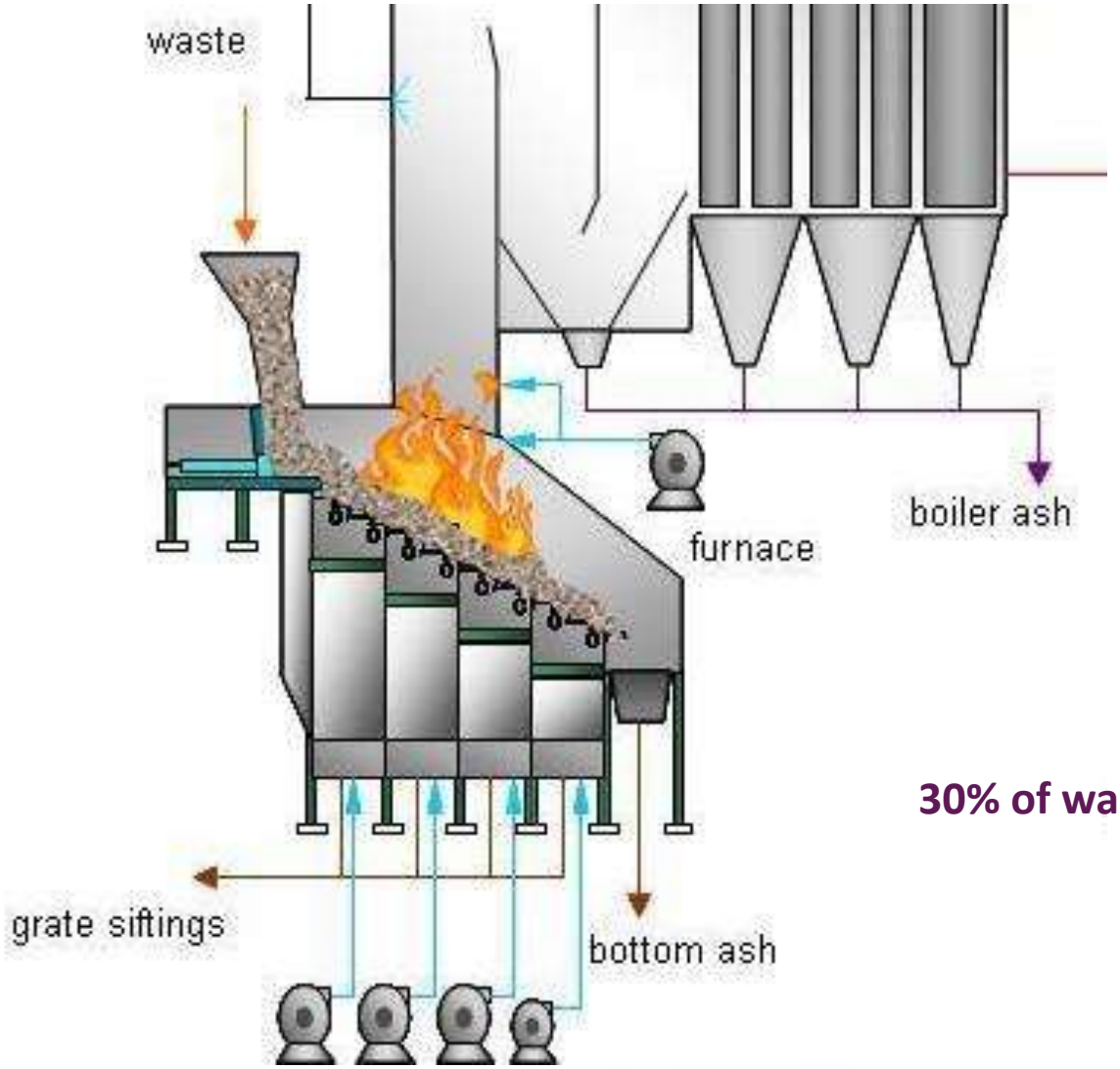
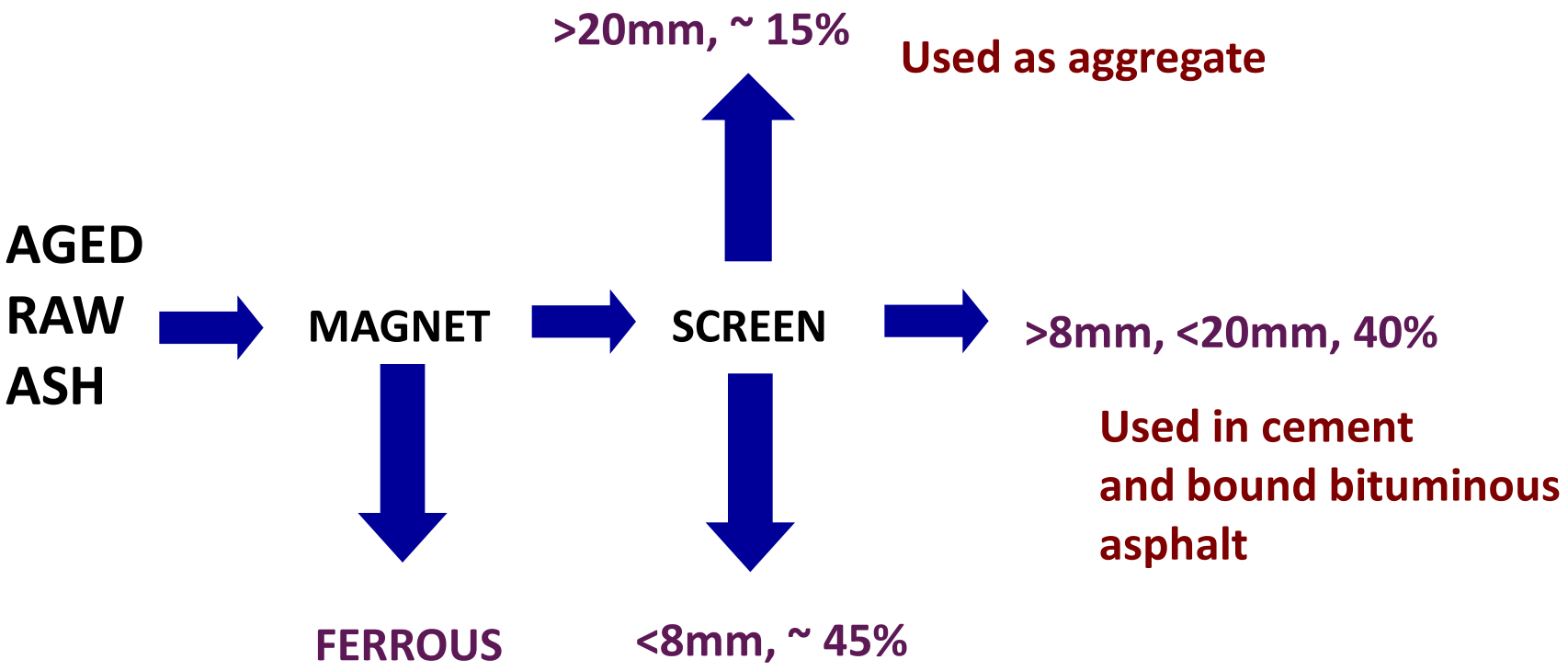
Combustion grate



30% of waste input is IBA

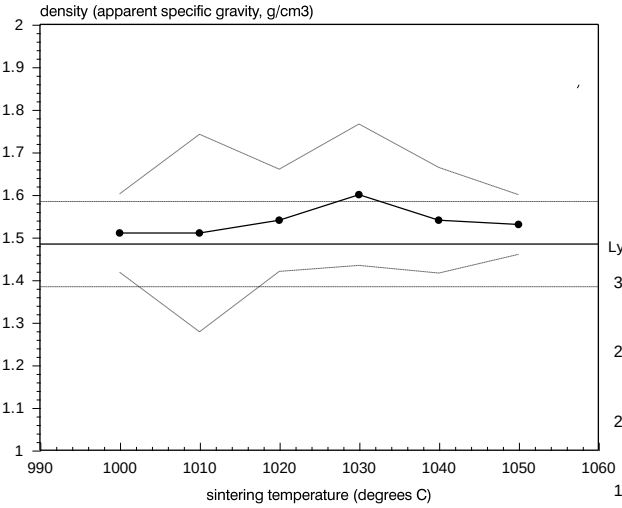
Bottom ash recycling plant



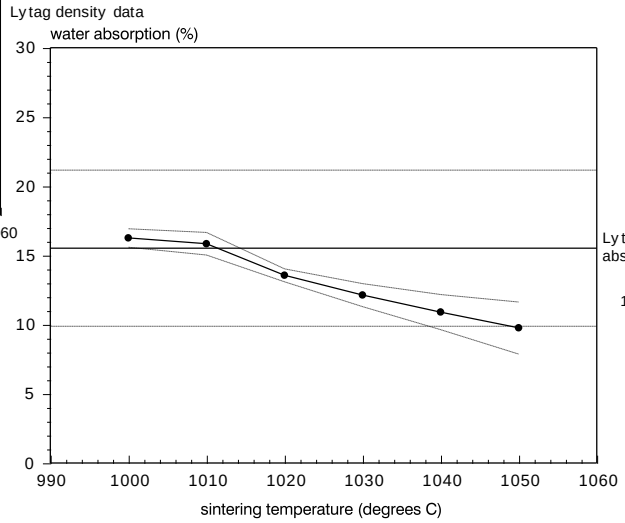
Production process

milling → pelletising → drying → sintering → LWA product

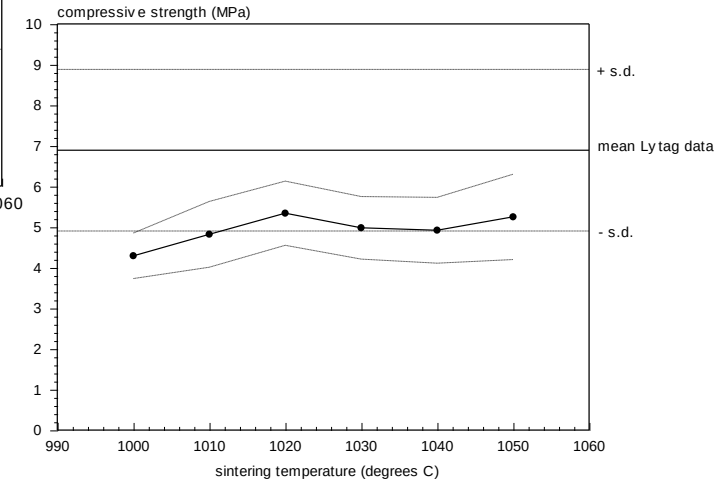
Key properties



Density

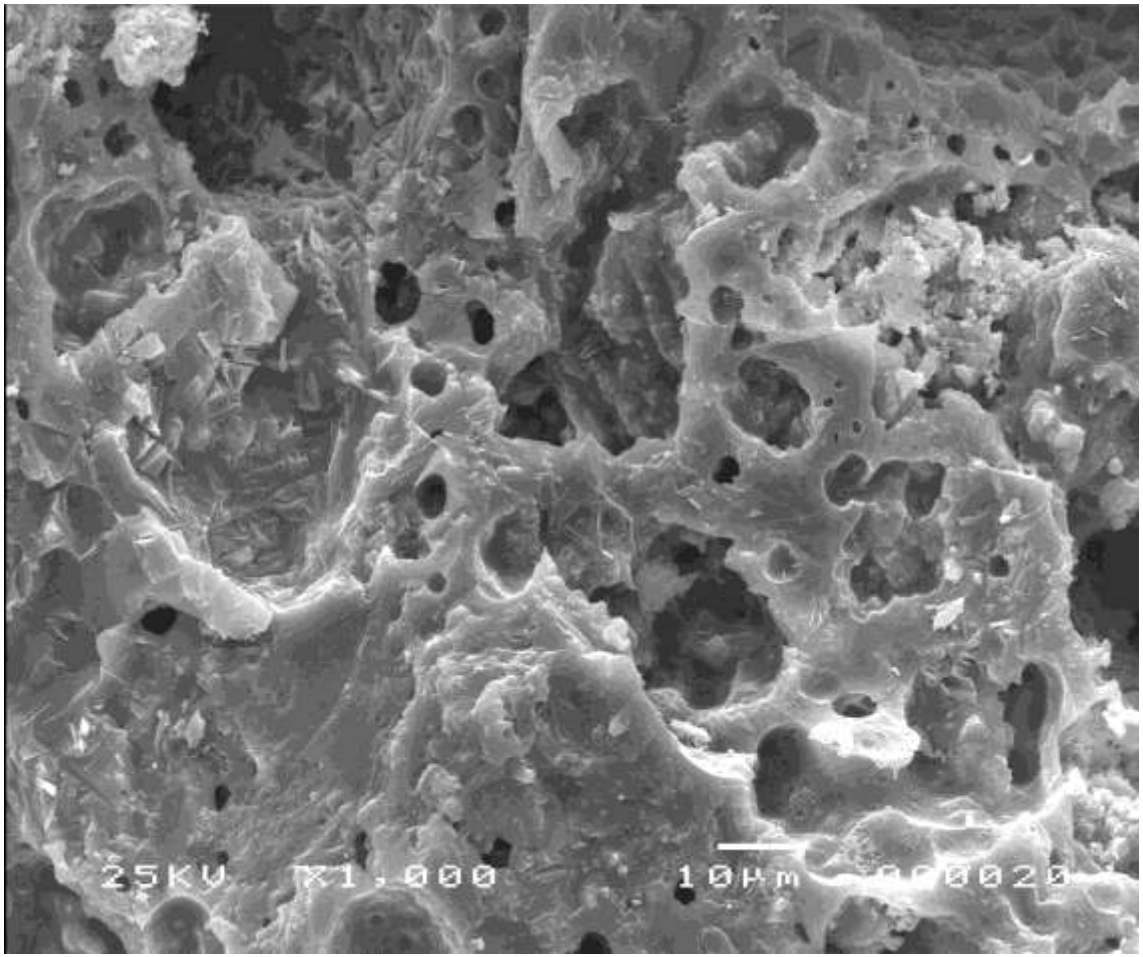


Water absorption



Compressive strength

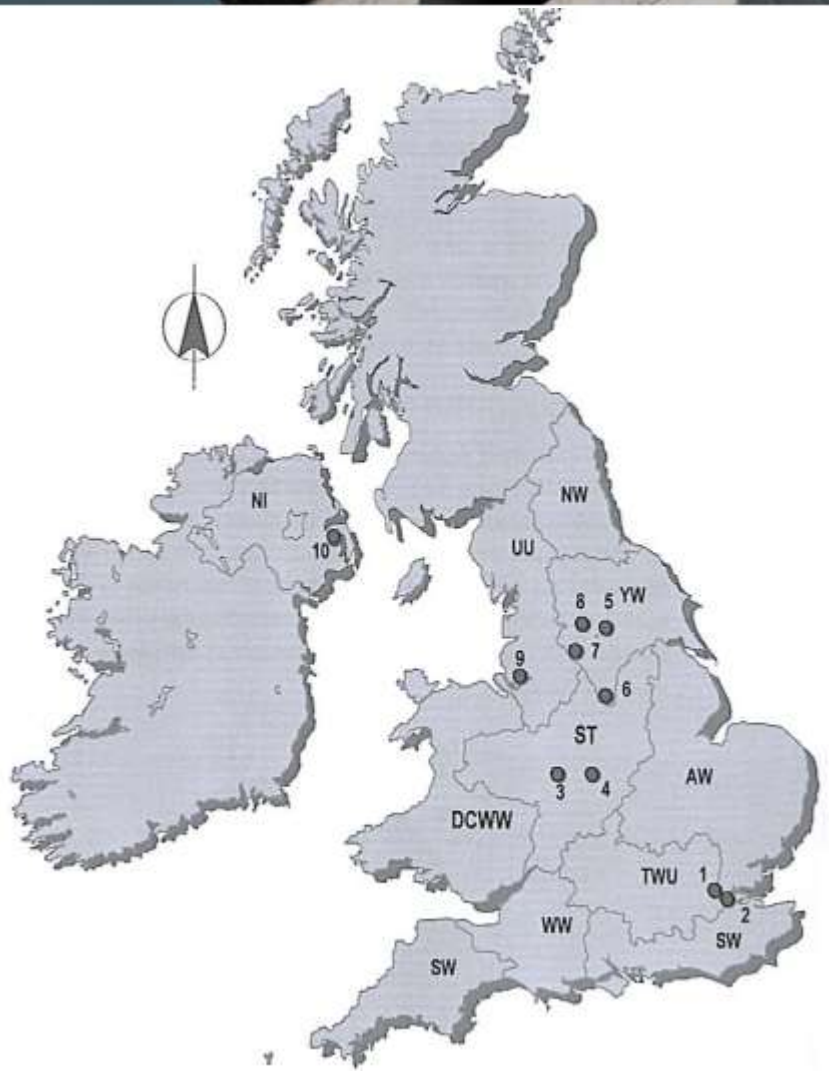
Microstructure



Microstructure of milled IBA pellet rapidly sintered at 1020°C

Lightweight aggregate manufactured from sewage sludge ash

UK sewage sludge incinerators



1. Beckton: East London
2. Crossness: East London
3. Roundhill: Stourbridge
4. Coleshill: Birmingham
5. Leeds
6. Sheffield
7. Huddersfield
8. Bradford
9. Widnes
10. Belfast

UK sewage sludge incinerators

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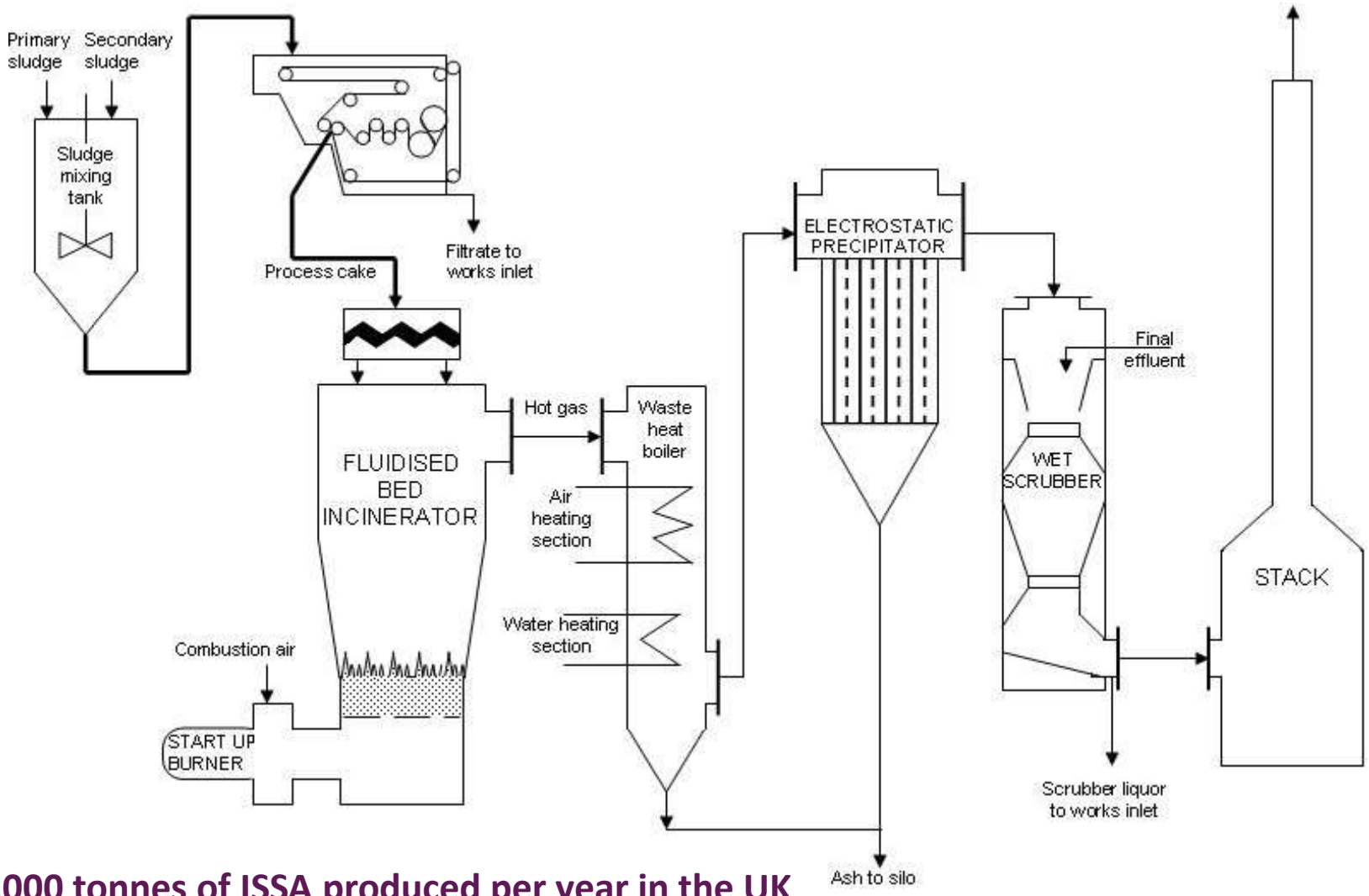
Fluidised bed sludge incineration



~100,000 tonnes of ISSA produced per year in the UK

Blackburn Meadows SEM with EDS

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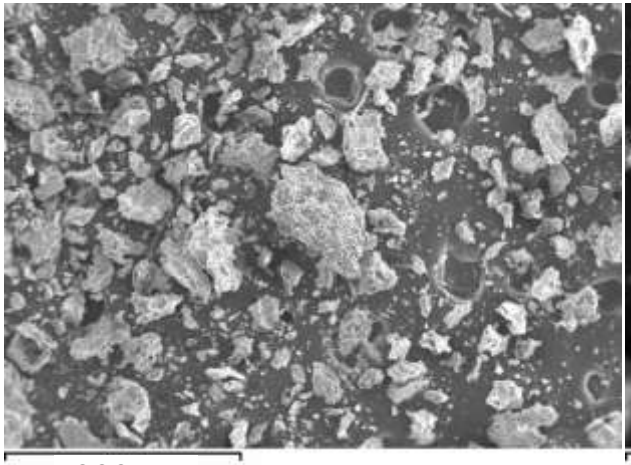
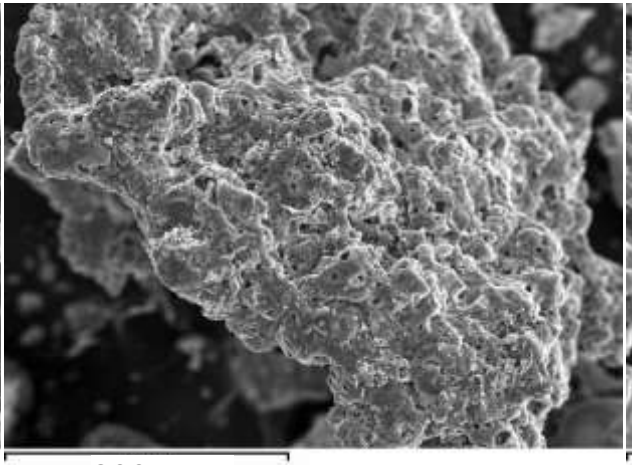
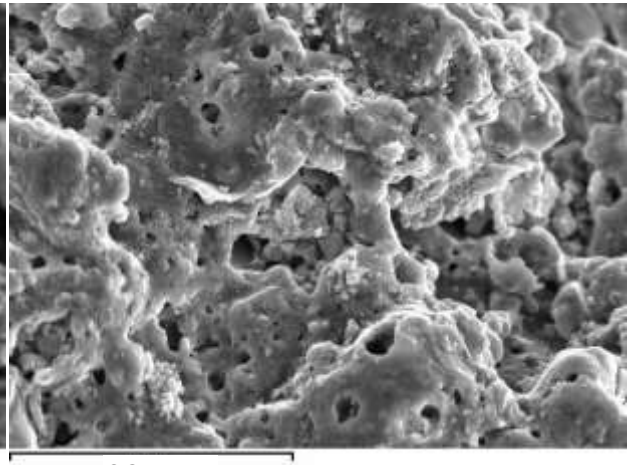


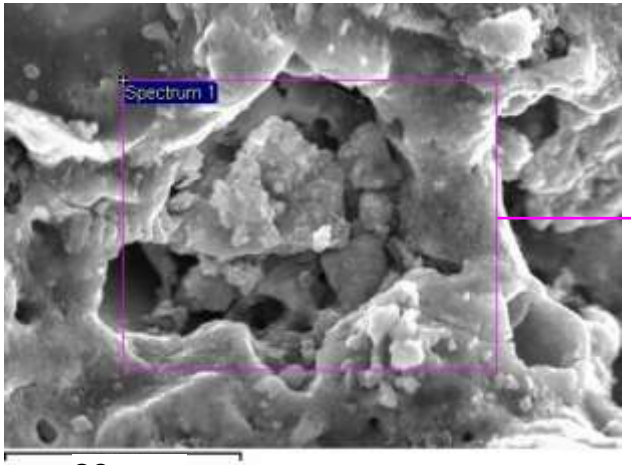
1000µm



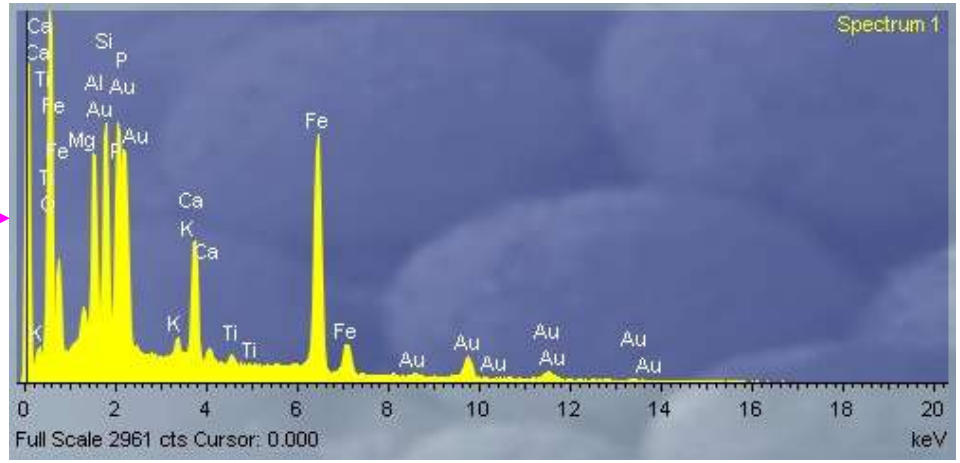
200µm



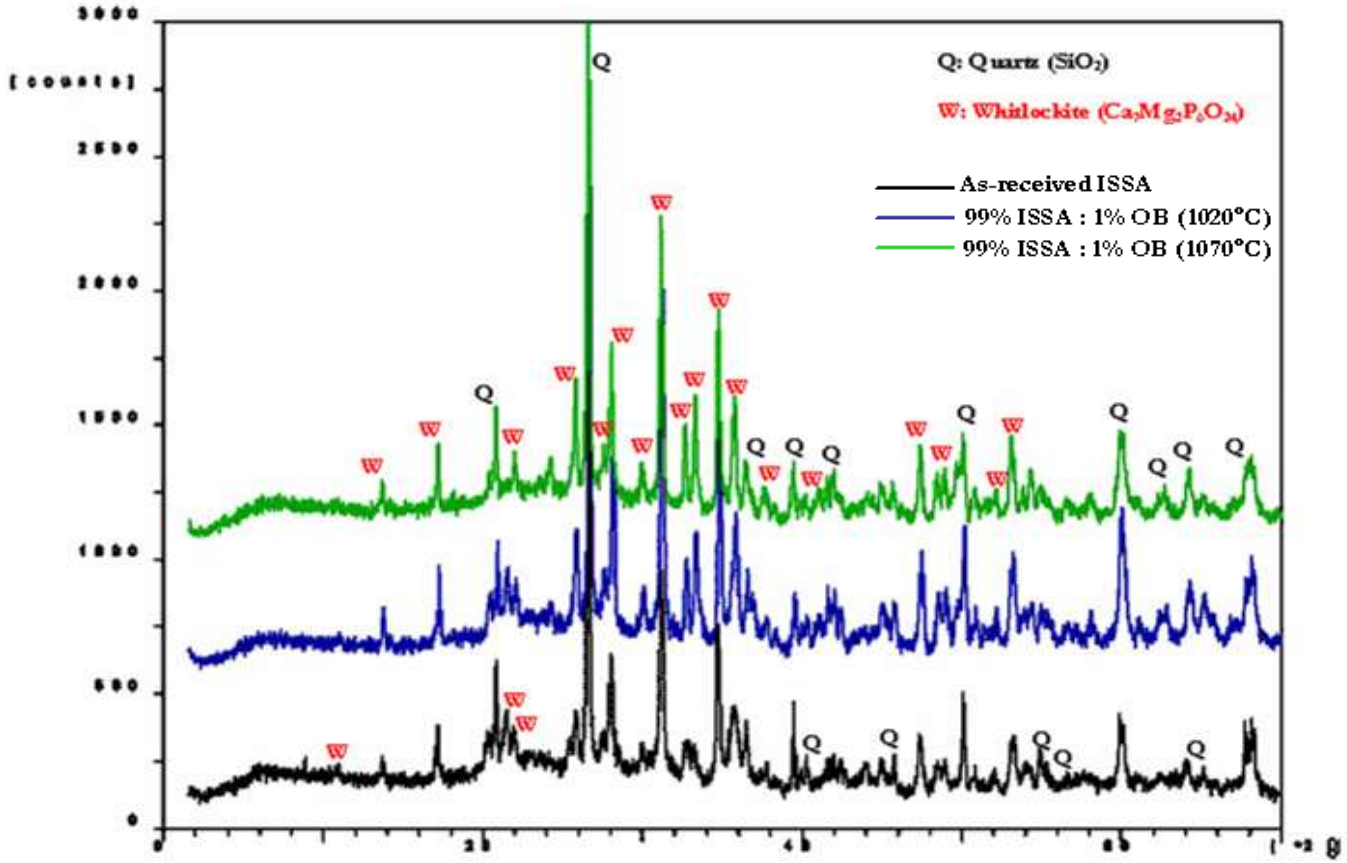
60µm



20µm



Crystalline phases



Key ISSA lightweight aggregate properties

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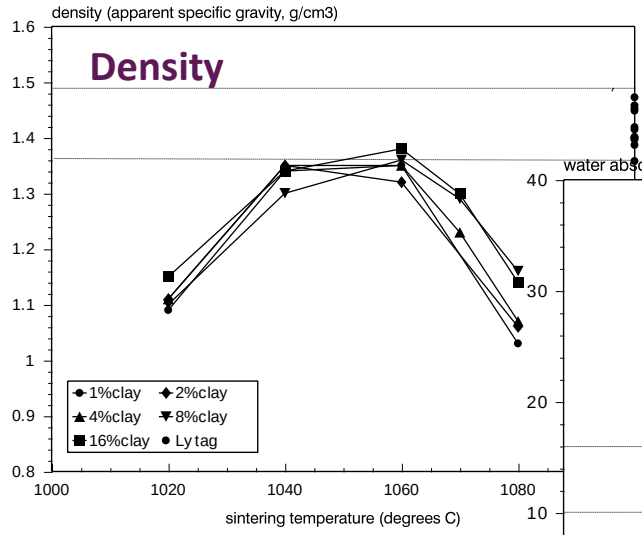

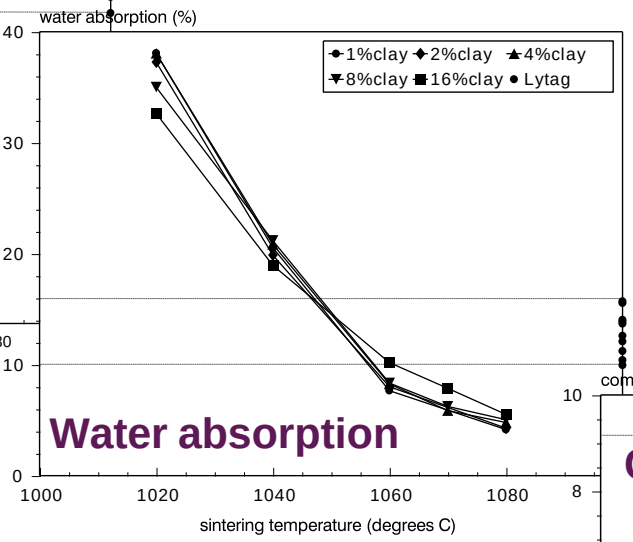

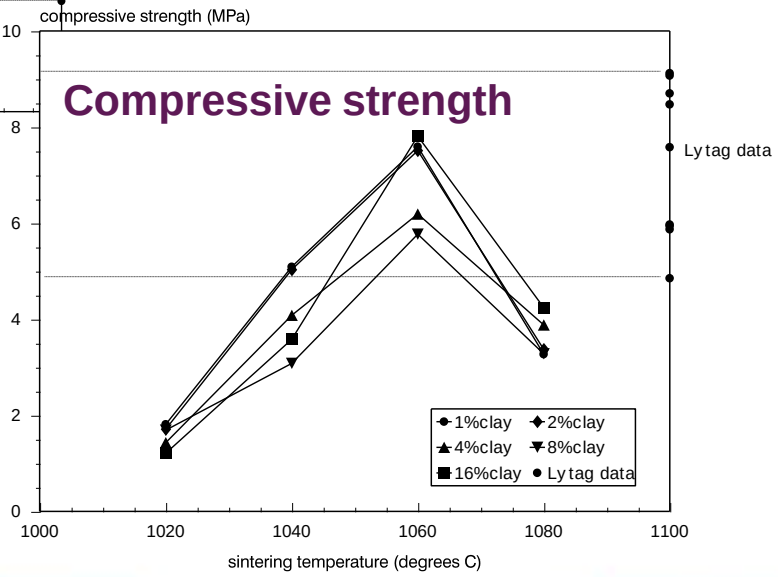

Effect of temperature on microstructure

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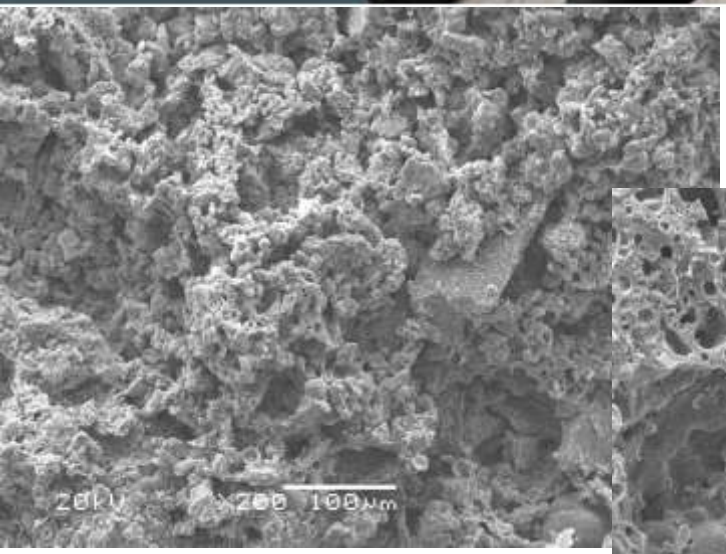
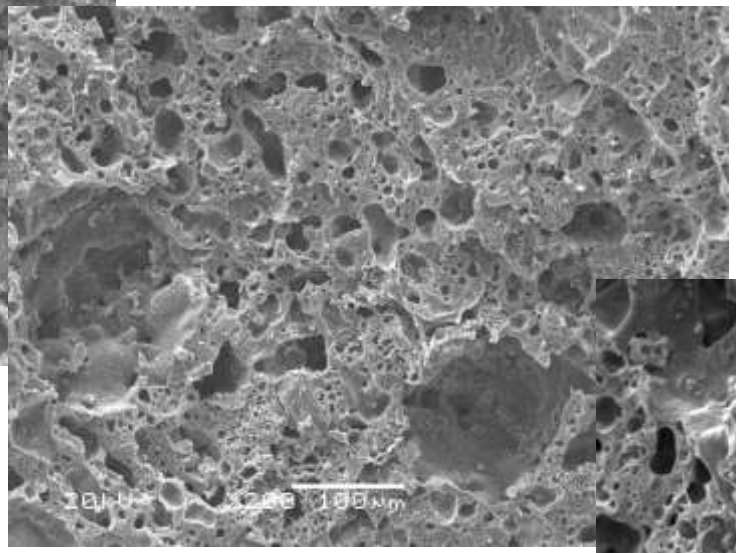
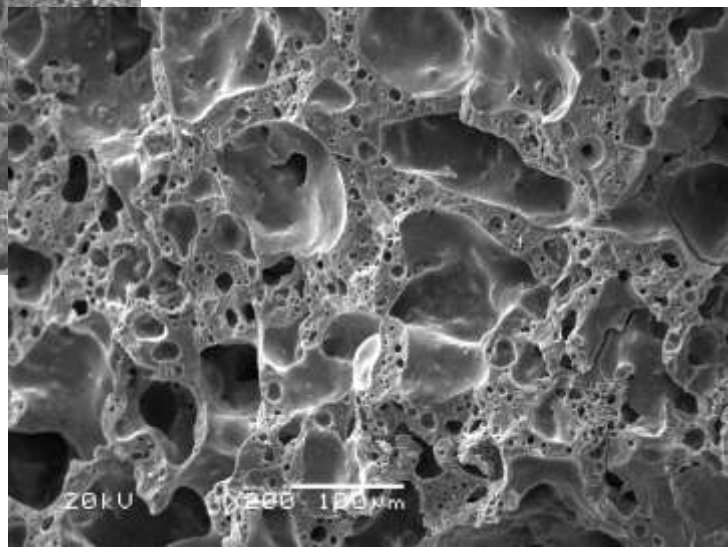
Fracture surfaces of ISSA LWA pellets



1020°C



1060°C



1070°C

Mechanisms occurring during rapid sintering of lightweight aggregate

Microstructural control

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Complex materials

Number of interacting effects

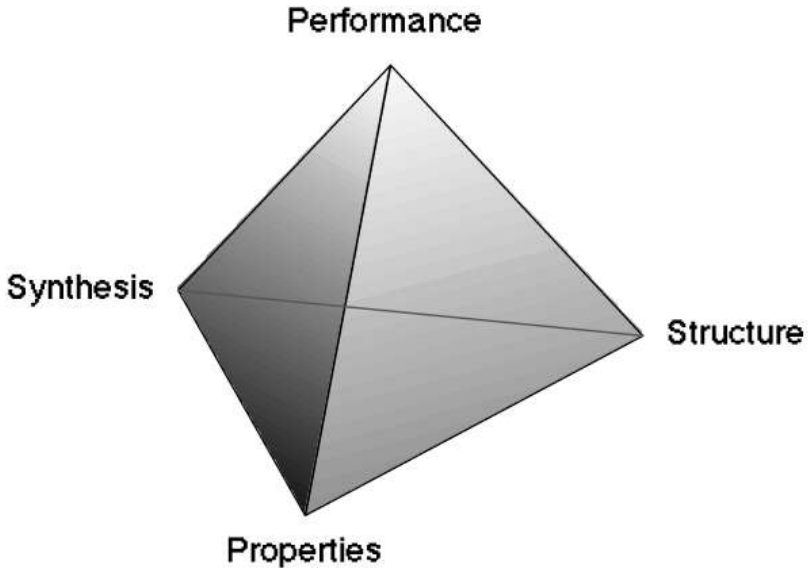
Reduced viscosity of the glass phase

Liquid phase sintering

Volatilisation of various components

Internal oxidation and reduction reactions

Formation of pozzolanic coating



Schematic microstructure 1

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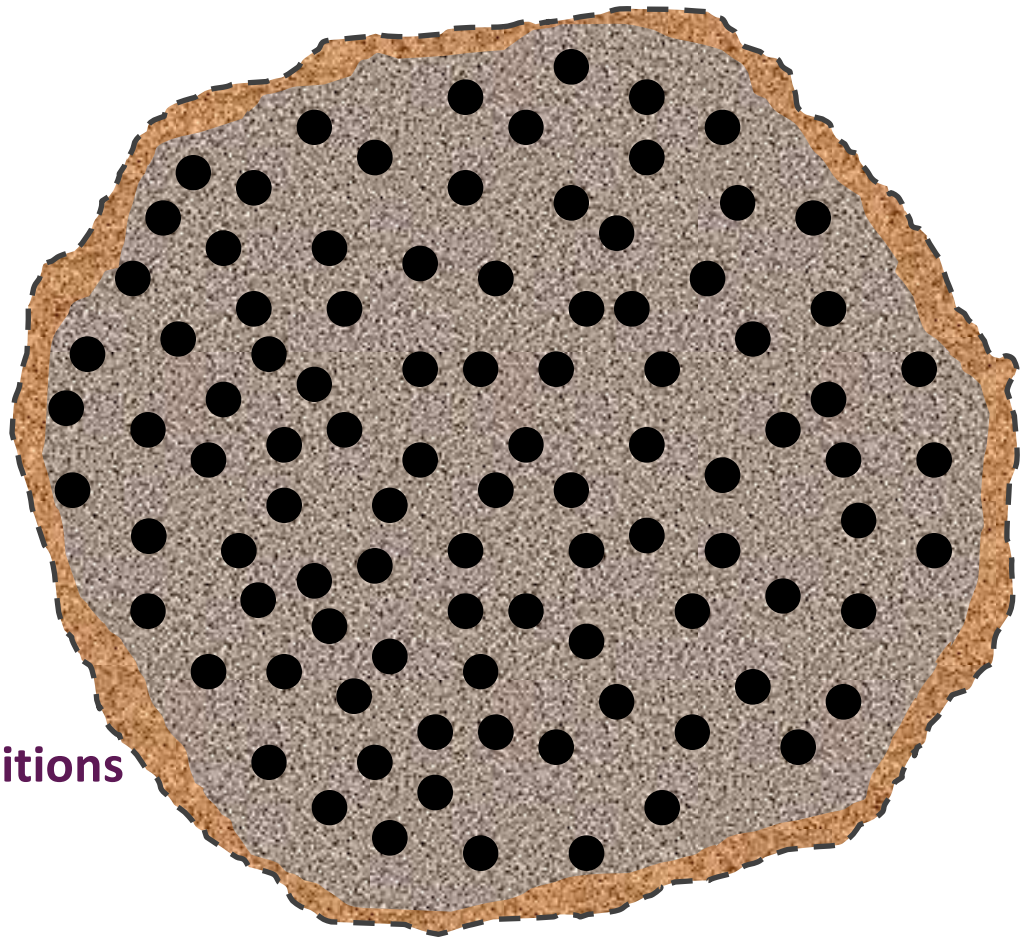
Ideal lightweight aggregate

- Strong core with uniform voids
- Dense surface coating
- Rough surface
- Approximately spherical
- 6 - 10 mm diameter
- CaO rich surface coating
- Black core due to reducing conditions



Schematic microstructure 2

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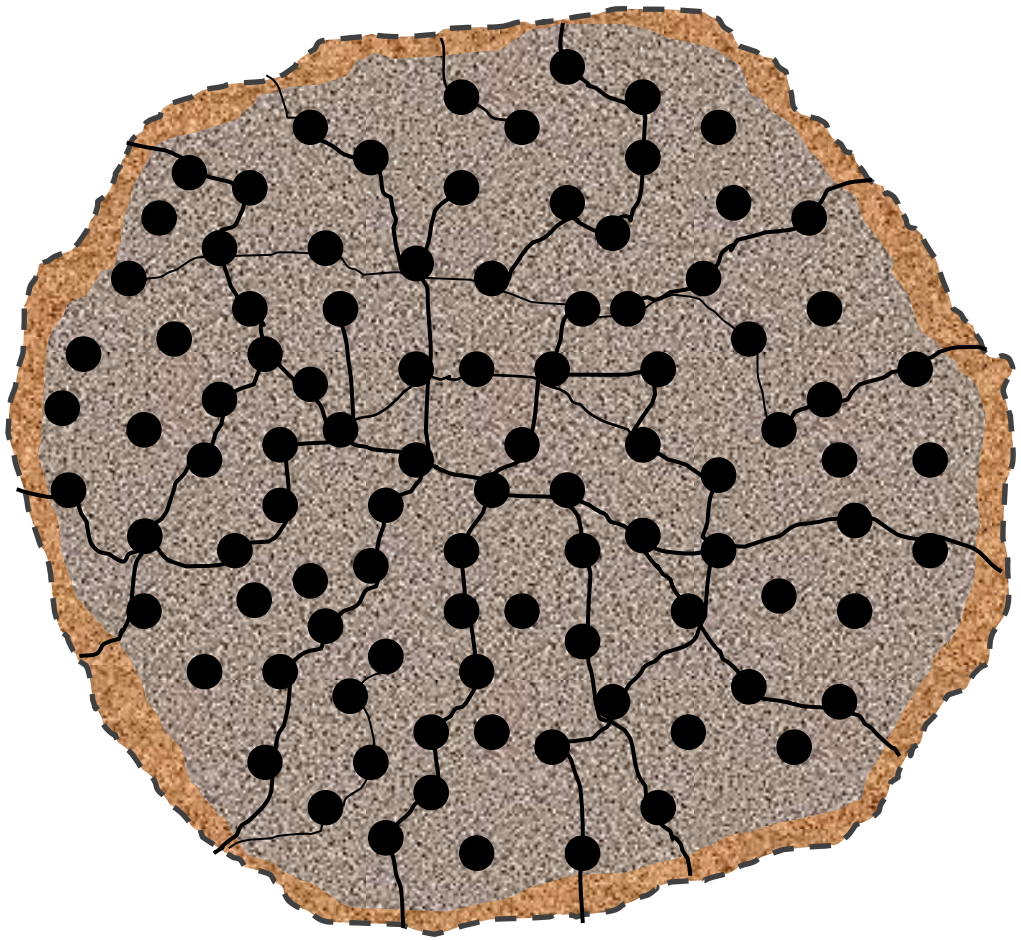
Formation of connected porosity

Results in high water absorption

and reduced compressive strength



Not ideal for structural concrete

Schematic microstructure 3

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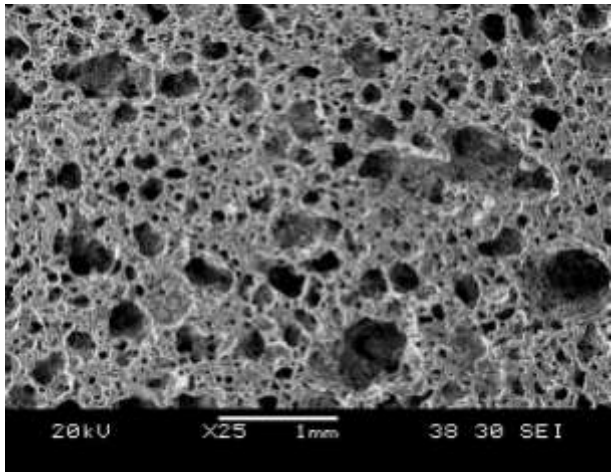
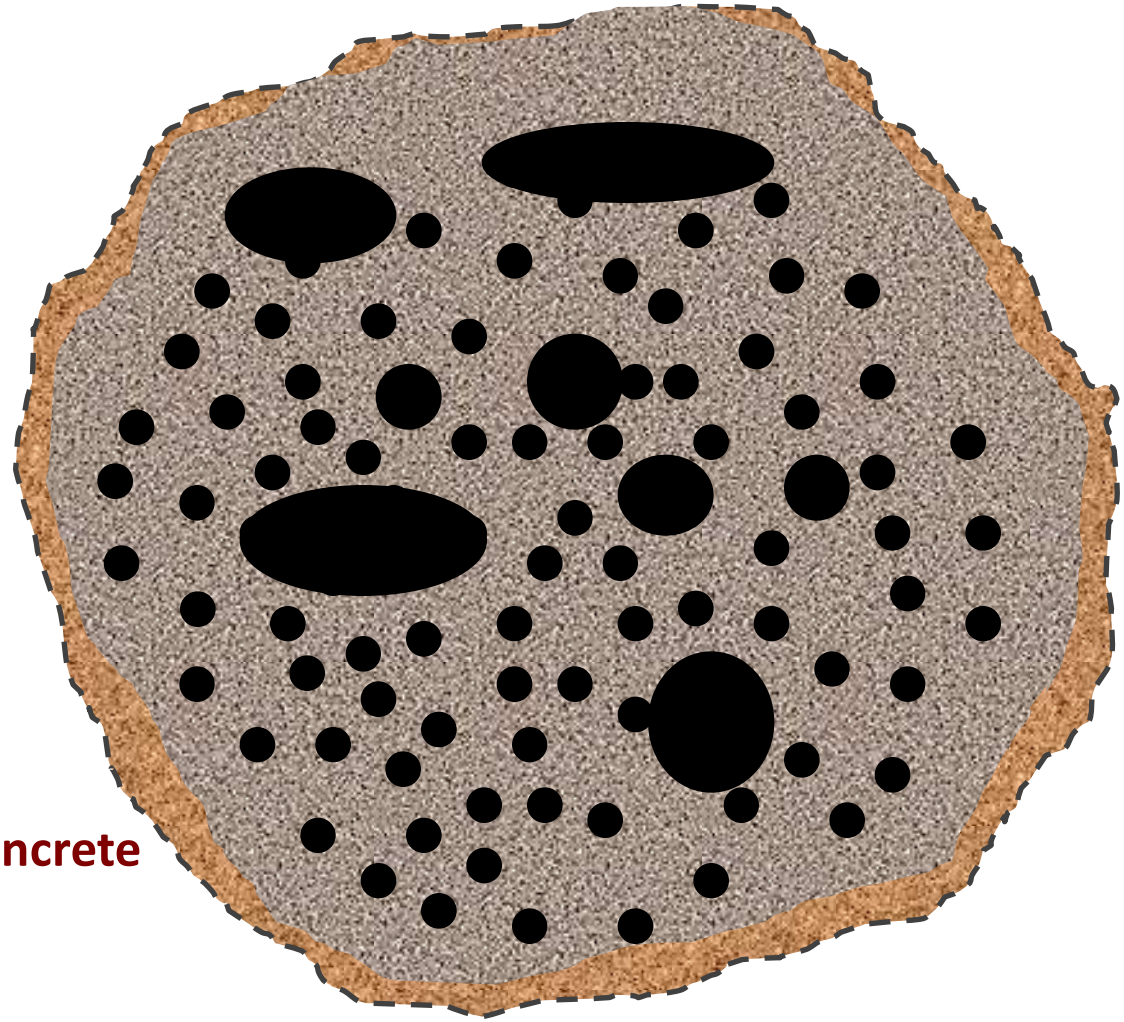
Marginally over-fired

Exaggerated growth of voids
Low density
High water absorption





Cannot be used for structural concrete

Schematic microstructure 4

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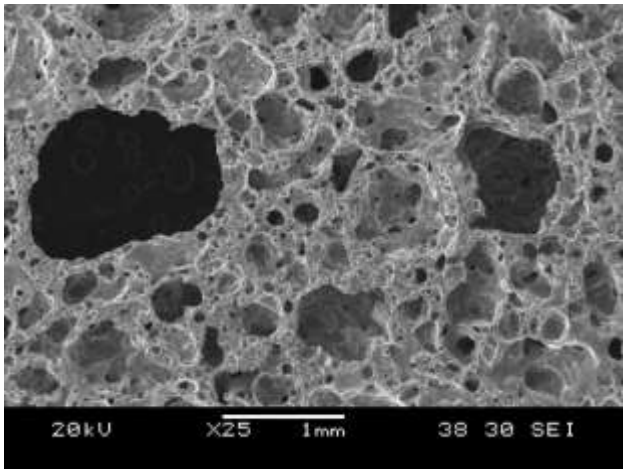
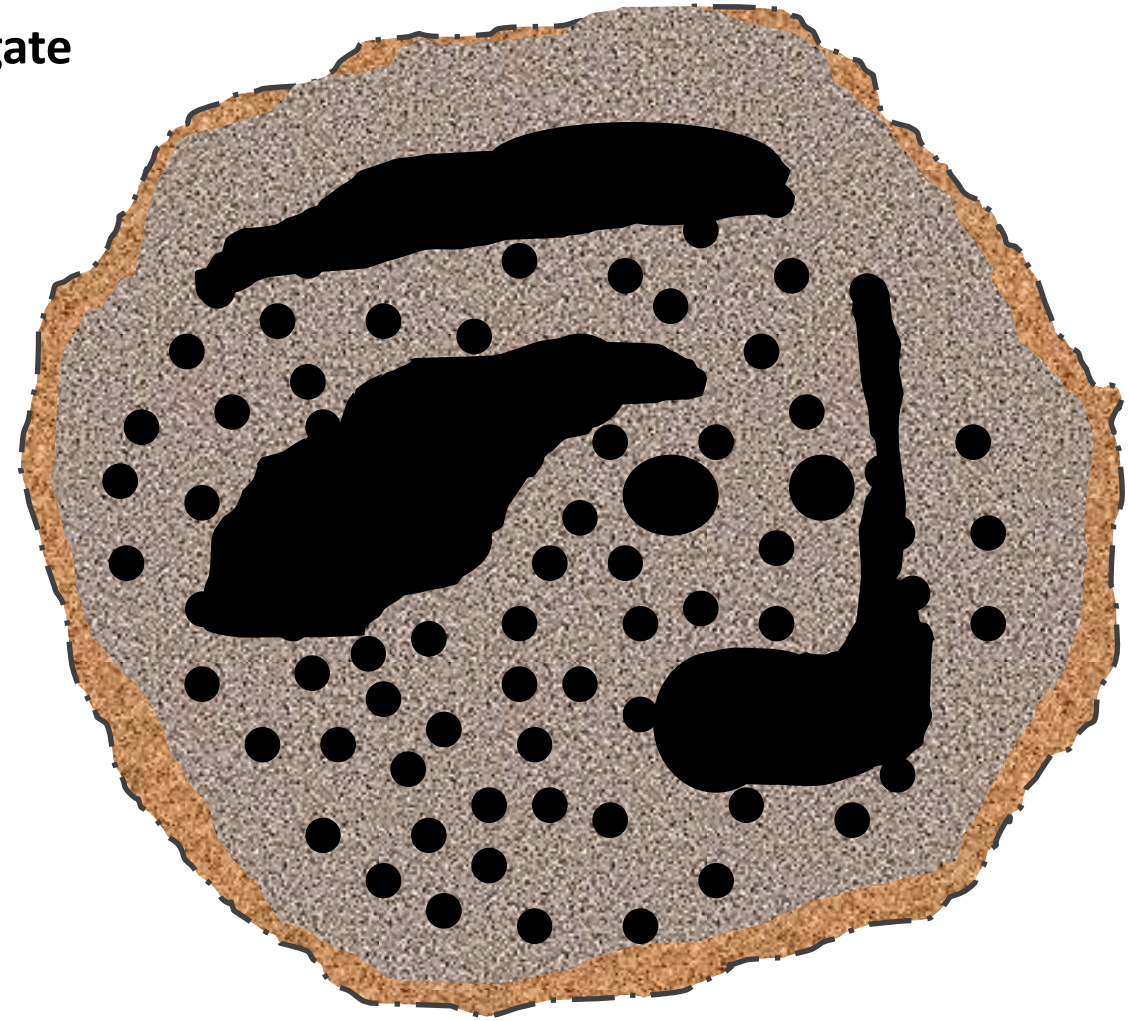
Over-fired lightweight aggregate

Bloated
Low density
Low strength
High water absorption





Schematic microstructure 5

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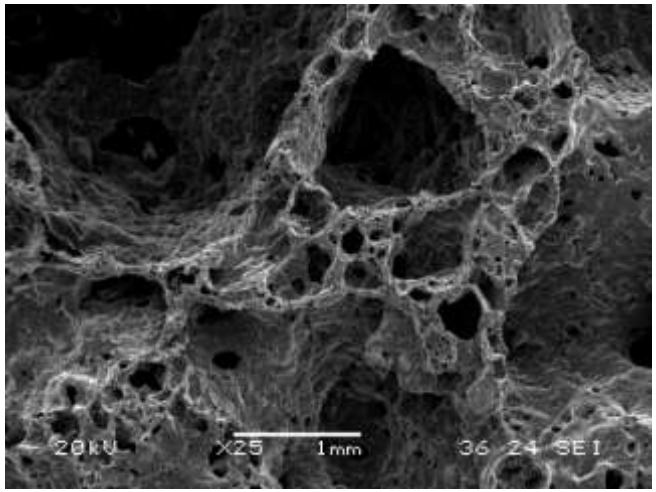
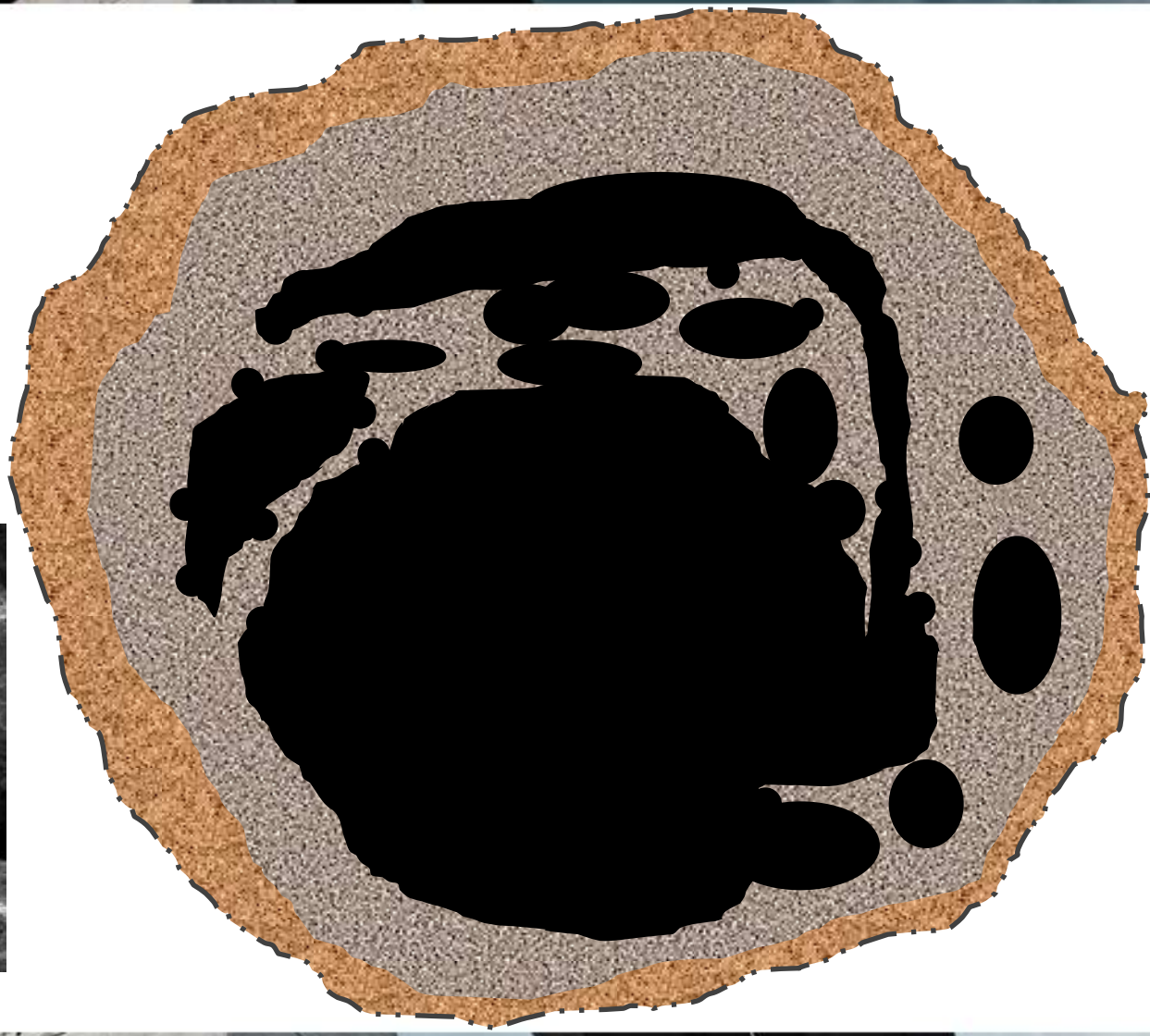
Over-bloated aggregate
Extremely lightweight

Over fired
Extremely low density
Very low strength
High water absorption





Conclusions

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Important drivers for increased resource efficiency

Beneficial reuse of residues from thermal treatment processes

Lightweight aggregate - Lytag from pulverised fuel ash

Other options using relatively simple processing

Control of mix design and processing

Engineered lightweight products with improved performance

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