Pilot-scale operational study of biomass usage in a fluidized bed combustor

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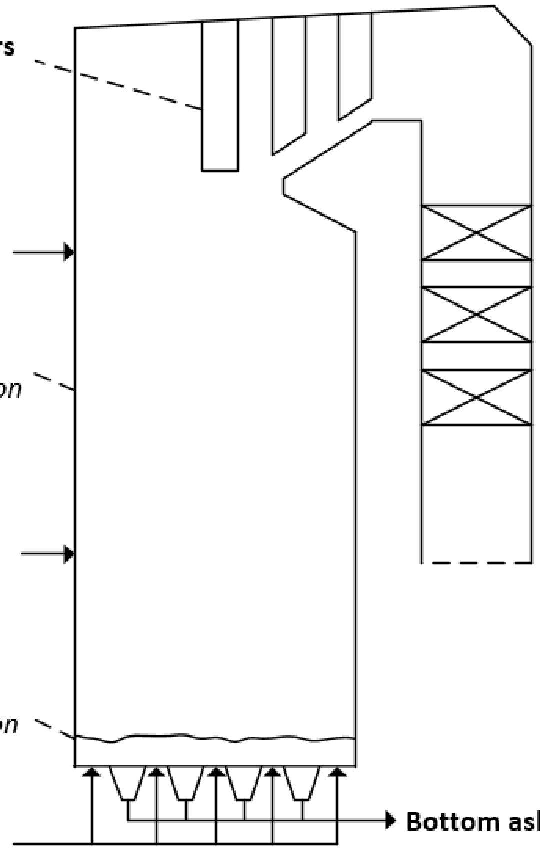
Fluidized Bed Combustion



Agglomeration

- Primarily driven by the reaction of alkali metals (K, Na) in biomass ash with silica in bed material or fuel ash:

$$K_2O + nSiO_2 \rightarrow K_2O \cdot nSiO_2$$

- Alkali silicate melts cover bed material, and cause it to stick together as agglomerates.
- **Defluidization** of the bed will occur without removal of bottom ash & replenishment of bed material.

Above: Example agglomerates from this study.

Sembcorp Utilities UK

Wilton International
Teesside, Middlesbrough
www.wiltoninternational.com

"Wilton 10"
35MW$_e$ Combined Heat & Power Station
Bubbling fluidized bed
Virgin wood + demolition wood blend

Experimental Objectives

- Mixed experimental conditions:
  - Fuel: white wood, wheat straw, oat hull waste
  - Bed material: sand vs. 3 different size grades of olivine
  - Static bed height: 19.1cm to 40.6cm
  - Different fluidizing gas velocities & thermal ratings
- Looking at effects on:
  - General operational behaviour
  - Defluidization time
  - Emissions
  - Agglomeration behaviour

Left: Image of 664µm olivine bed material prior to use.
Right: Bed condition after wheat straw/olivine test.

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sembcorp

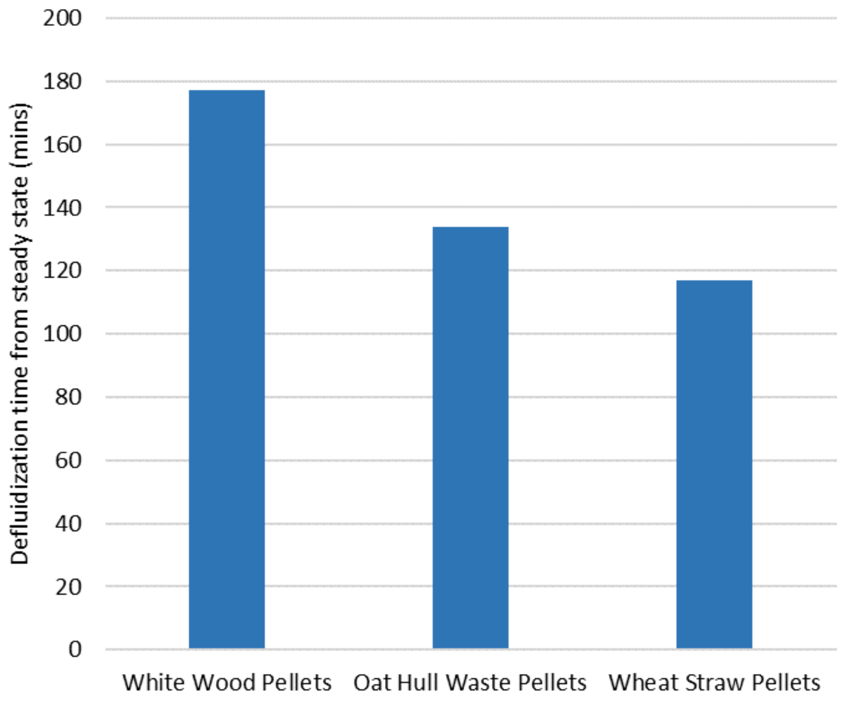
Methods & Equipment

- Pilot-scale bubbling fluidized bed
- 50-75kW_{th} in present study
- Temperature, pressure, & emissions monitoring
- Multiple fuel hoppers
- Recently fitted corrosion probe
- Key differences vs. equivalent commercial boiler:
  - Lack of secondary/tertiary air
  - Lack of bed/bottom ash screws

Above: Pilot-scale fluidized bed combustor used.

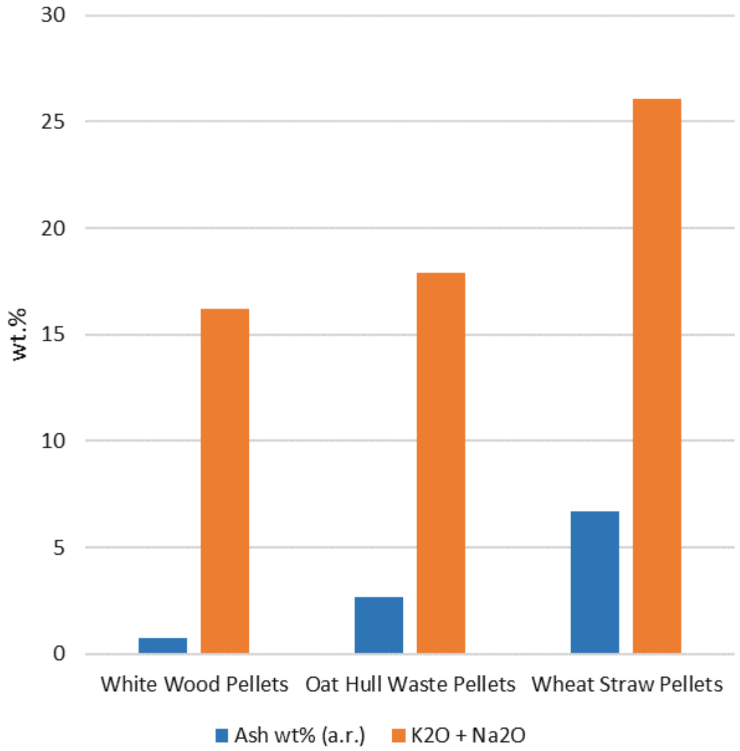
Fuel

Defluidization Time

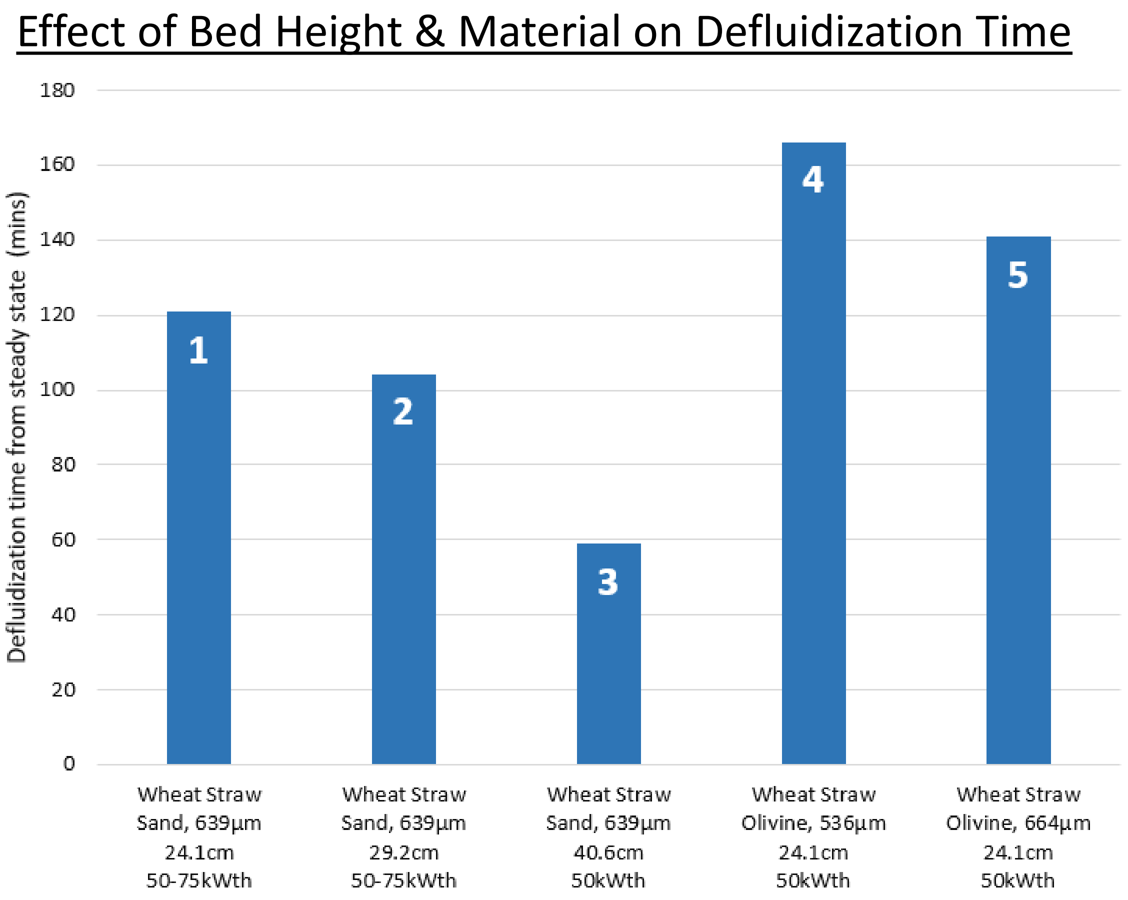


Conditions: Sand bed, 24.1cm bed height, $3U/U_{mf}$, $50kW_{th}$

Fuel Ash Composition



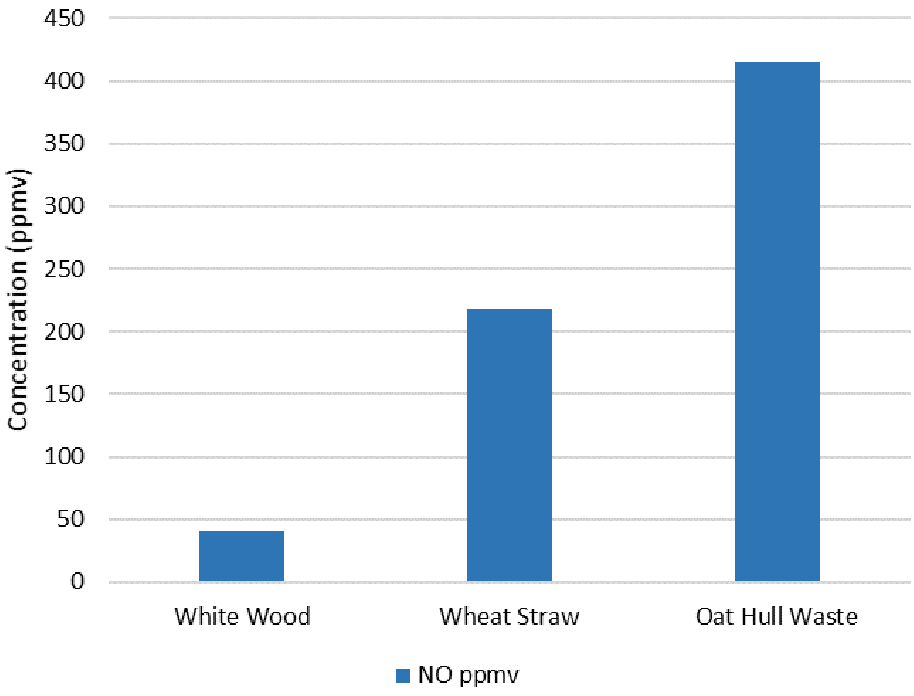
Bed Height & Material



Component	Sand (wt%)	Olivine (avg. wt%)
SiO_2	97.15	41.90
MgO	-	47.90
Fe_2O_3	1.96	7.16
Al_2O	0.28	0.89
K_2O	0.05	0.07

Emissions

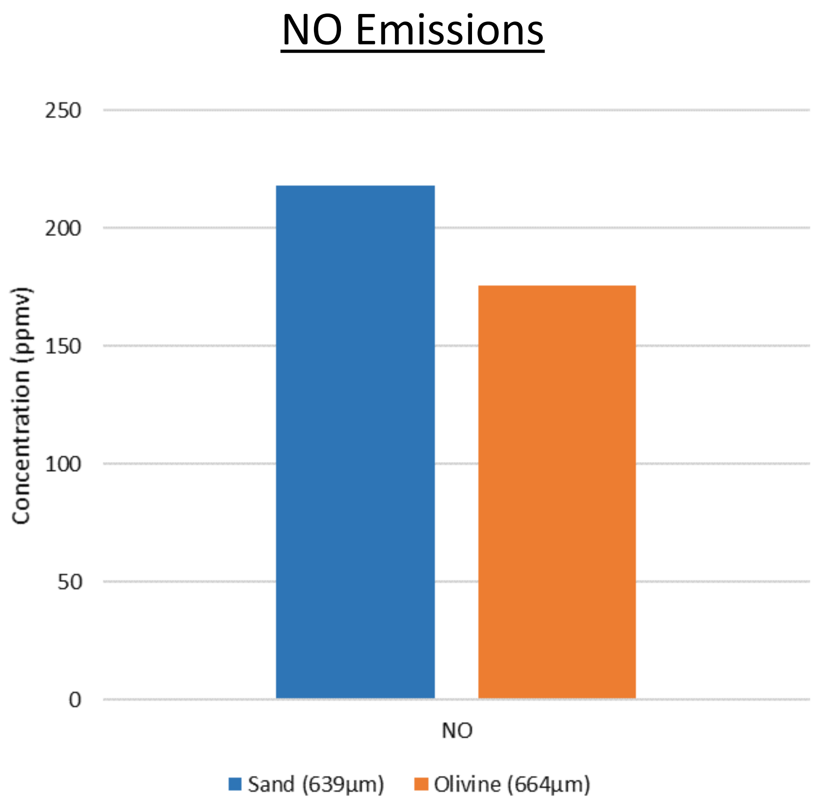
NO Emissions by Fuel



Emissions corrected for 6% O_2 in flue gas.
Conditions: Sand bed, 24.1cm bed height, $3U/U_{mf}$, $50kW_{th}$

Fuel	N Content (wt.%)	Avg. Bed Temp. (°C)	Combstn. Efficiency	SO_2 Emissions (ppmv)
White Wood	0.20	895	99.63%	3
Wheat Straw	0.88	850	99.62%	1
Oat Hull Waste	1.10	862	99.83%	4

Bed Material & Emissions



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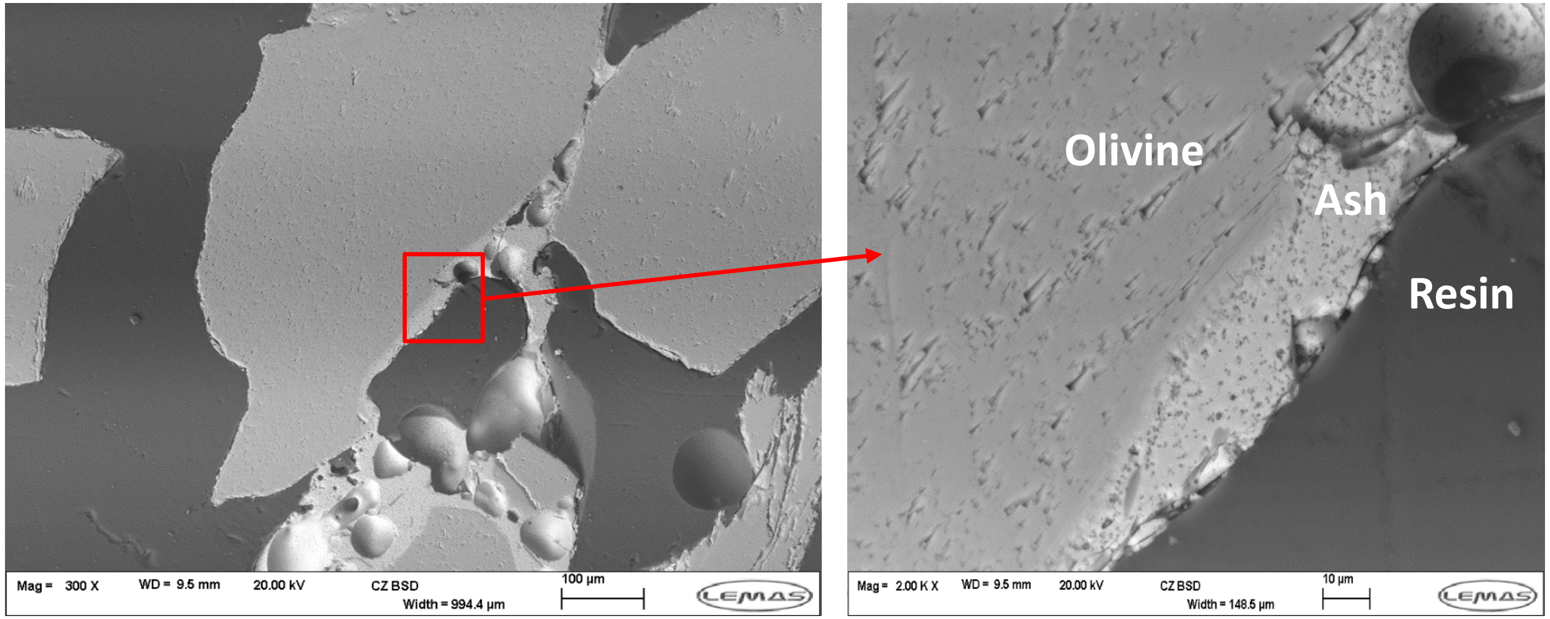
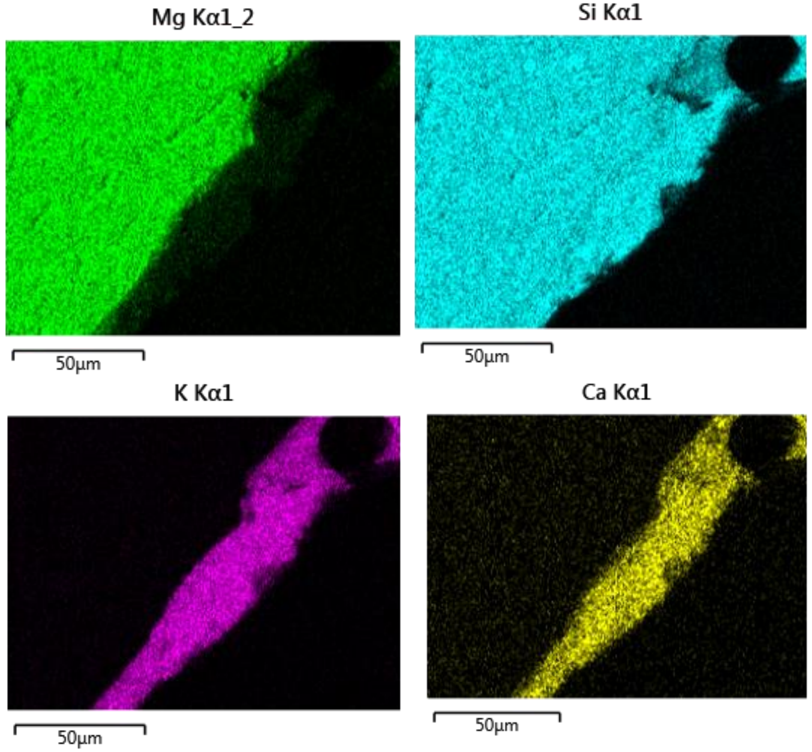
Al_2O_3	0.28	0.89
K_2O	0.05	0.07
Cr_2O_3	-	0.36
Mn_3O_4	-	0.10
ZrO_2	-	0.06
CaO	-	0.32
Combstn. Efficiency	99.62%	99.51%

SEM/EDX – Ash Layering

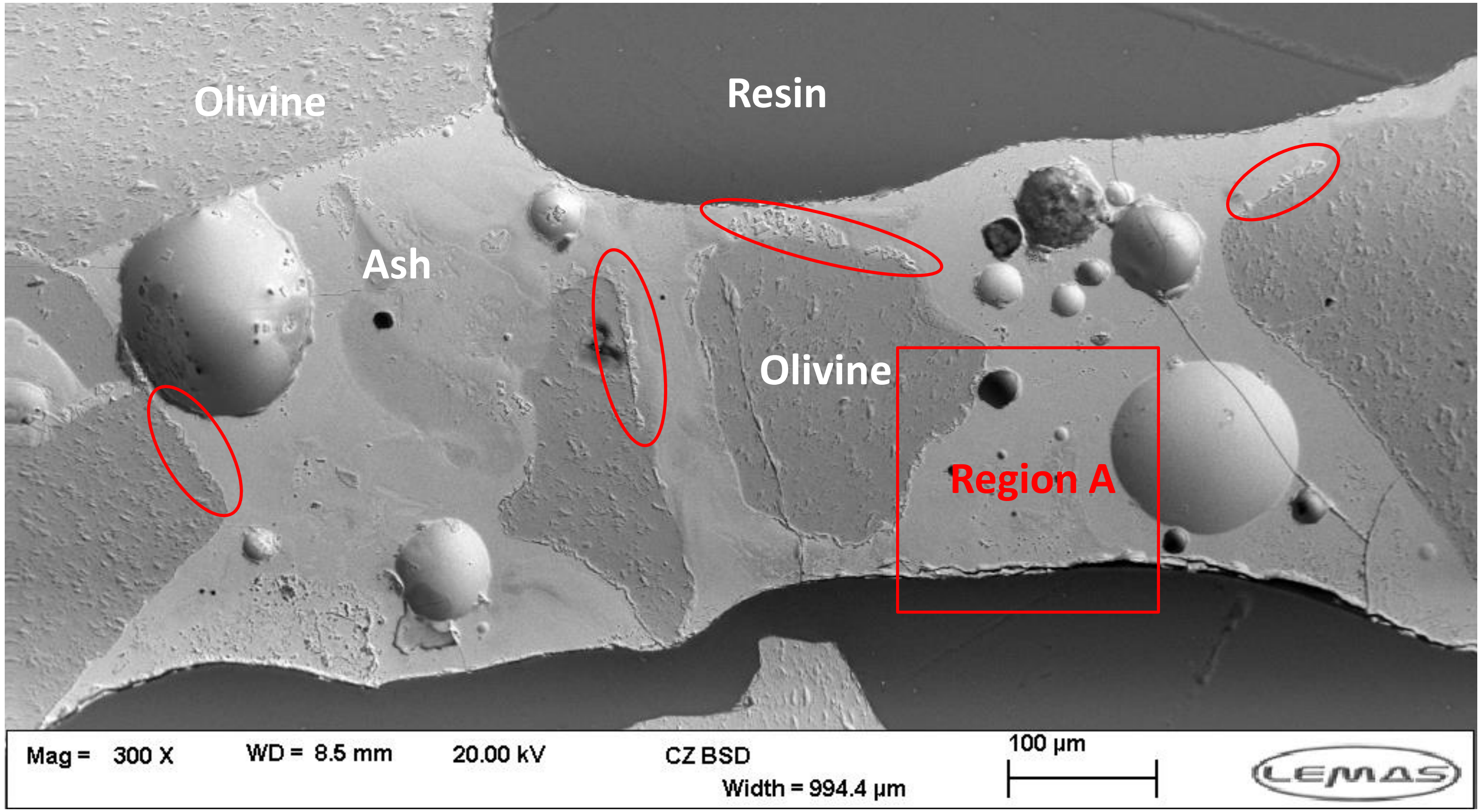




<u>Conditions:</u> Wheat Straw, 50kW$_{th}$, Olivine (664µm), 24.1cm bed height

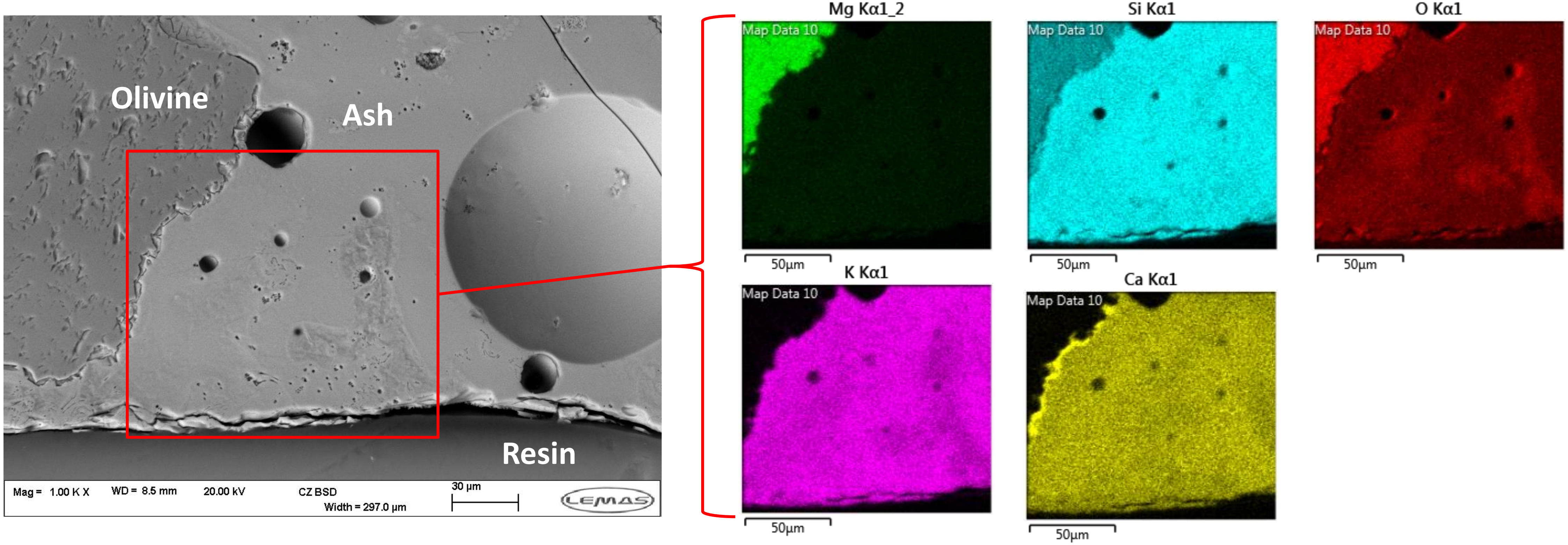
No apparent interaction between ash melt and olivine bed particle – ash layer derived entirely from fuel ash.

SEM/EDX – Calcium behaviour



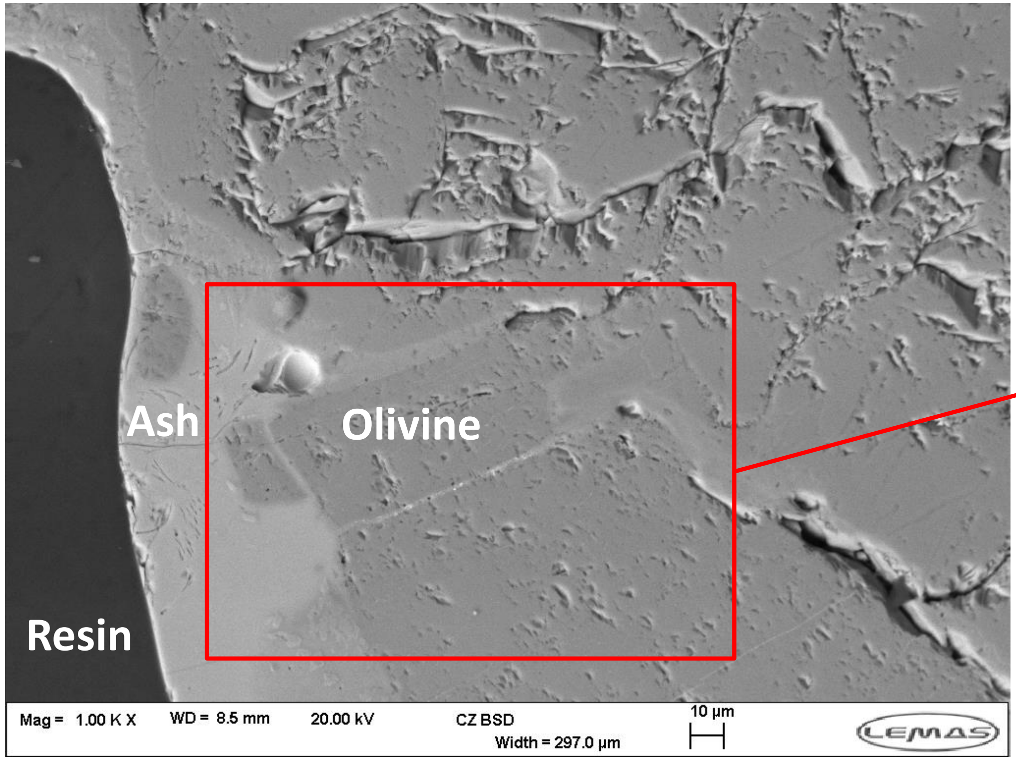
<u>Conditions:</u> Wheat Straw, 50kW$_{th}$, Olivine (536µm), 24.1cm bed height

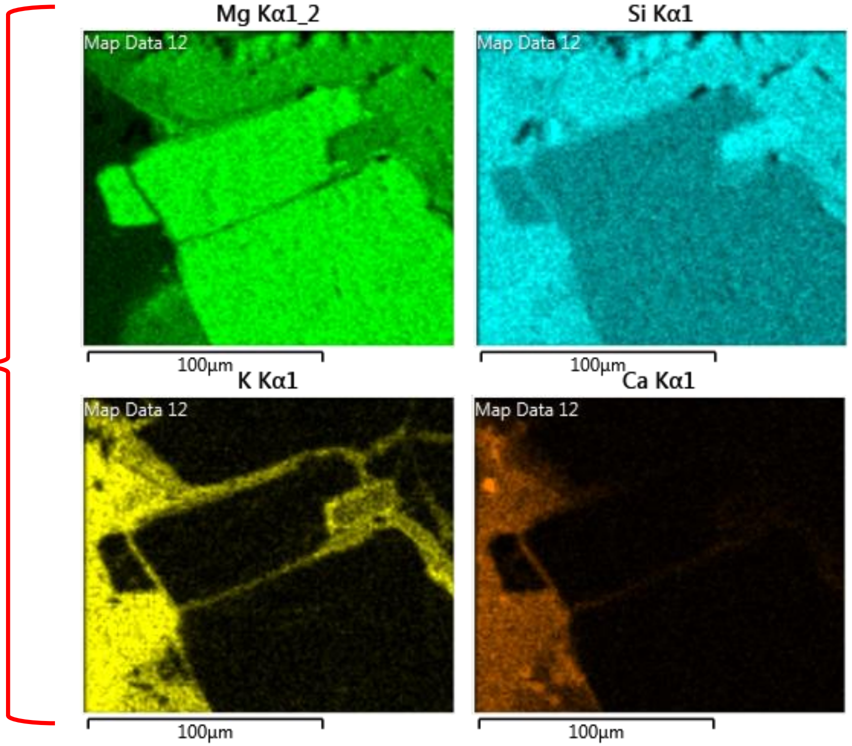
SEM/EDX – Calcium behaviour



Conditions: Wheat Straw, 50kW$_{th}$, Olivine (536µm), 24.1cm bed height
Increased calcium concentration at bed particle surface observed in some samples.

SEM/EDX – Melt behaviour in cracks



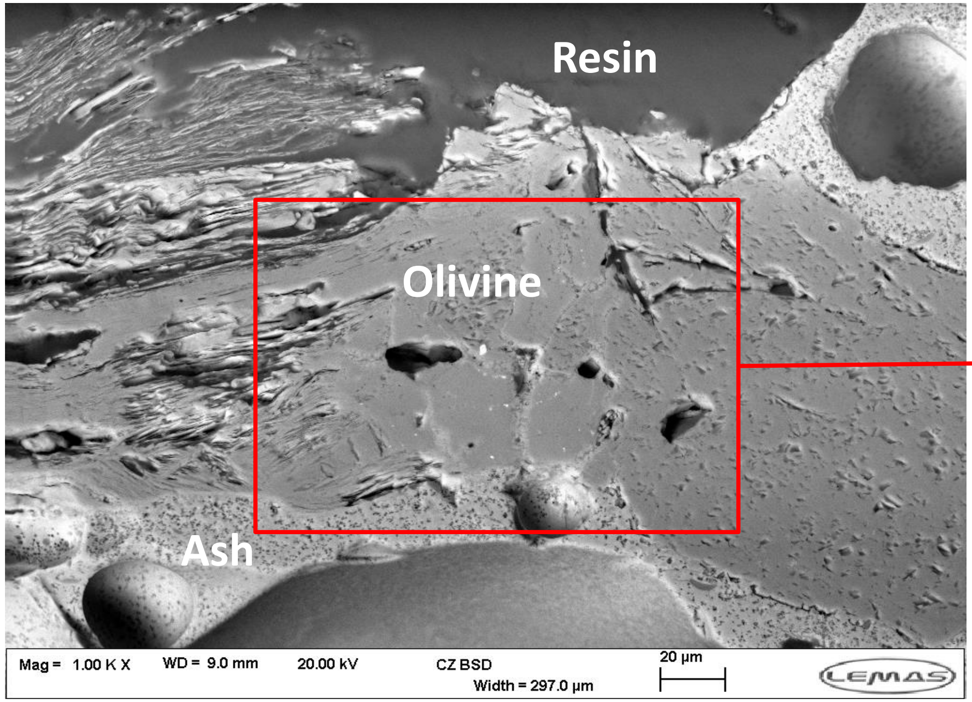


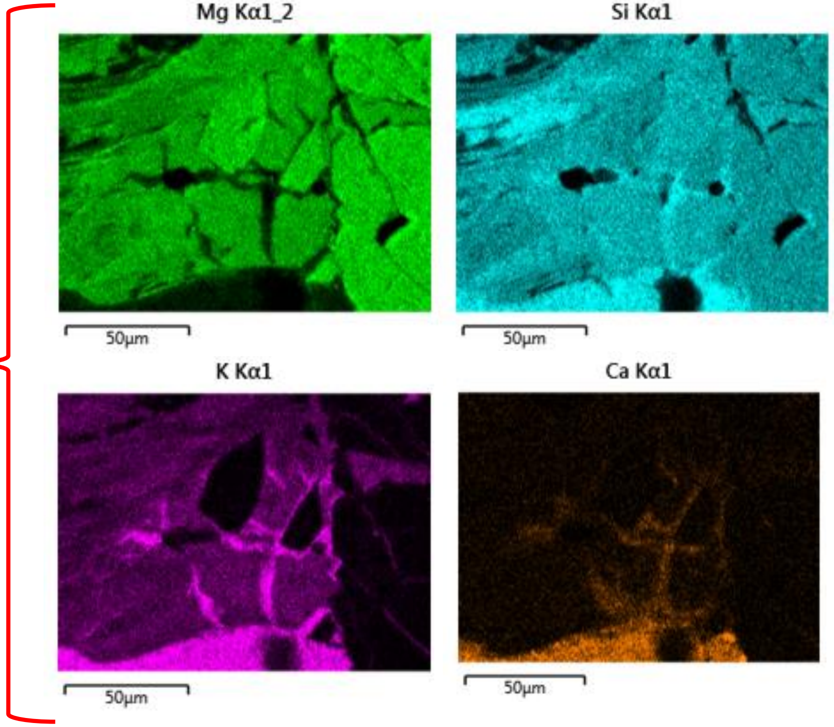
Conditions: Wheat Straw, 50kW$_{th}$, Olivine (536µm), 24.1cm bed height

Potassium from the ash melt was present far deeper into cracks and fractures than calcium in the olivine.

Shows high mobility of K-Si fraction of fuel ash melt.

SEM/EDX – Melt behaviour in cracks





<u>Conditions:</u> Wheat Straw, 50kW$_{th}$, Olivine (536µm), 24.1cm bed height

Another example of the highly penetrative potassium melt in bed material cracks, when compared to calcium melt fractions.

Conclusions

- White wood has fewer agglomeration issues compared to oat hull waste and wheat straw.
- Larger bed heights & larger bed particle sizes shorten defluidization times.
- Clear benefit to olivine as a bed material for mitigating agglomeration issues.
- Ash melts in presence of olivine do not appear to react with olivine, though calcium rich layer does form in some situations on bed particle surface.
- K-Si ash melt fractions move deeper into olivine fractures than Ca.

Thank you for listening
Any questions?

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