

Upgraded mineral sand fraction from MSWI bottom ash: an alternative solution for the substitution of natural aggregates in concrete applications

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World Sustainable Built Environment Conference Hong Kong
5-7 June 2017



Organisers:



International Co-owners:



Plan of presentation

- Introduction
- Materials and methods
- Results and discussion
- Conclusions and outlook



Organisers:



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Sustainable Buildings and Climate Initiative
Promoting Policies and Practices for Sustainability



Context of research

National production of natural aggregates (France)

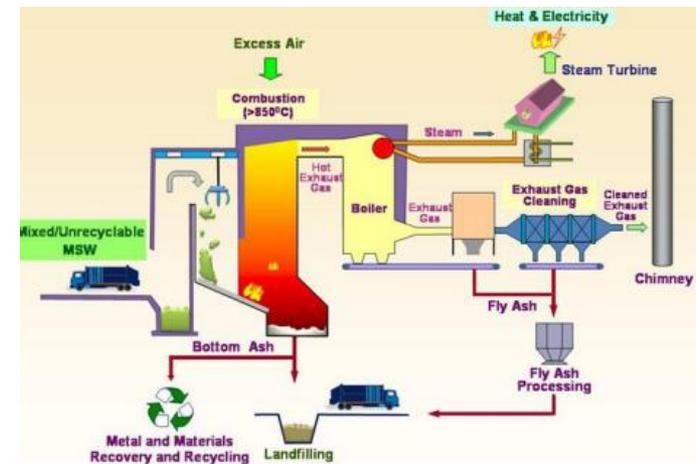
- 325,6 million of tons (2014)
- 302,3 million of tons (2015)
- **Supply needs in construction sector: about 430 million of tons**

Sustainable solutions are required

- **Which?**

Use recycled materials

- **Bottom ash from MSWI**



Waste-to-Energy plants

Context of research

Statistics and reuse of BA as secondary construction material (2010)

- 5 million of tons (Germany)
- **3 million of tons (France)**
- 1.6 million of tons (Netherlands)
- 1.27 million of tons (Italy)

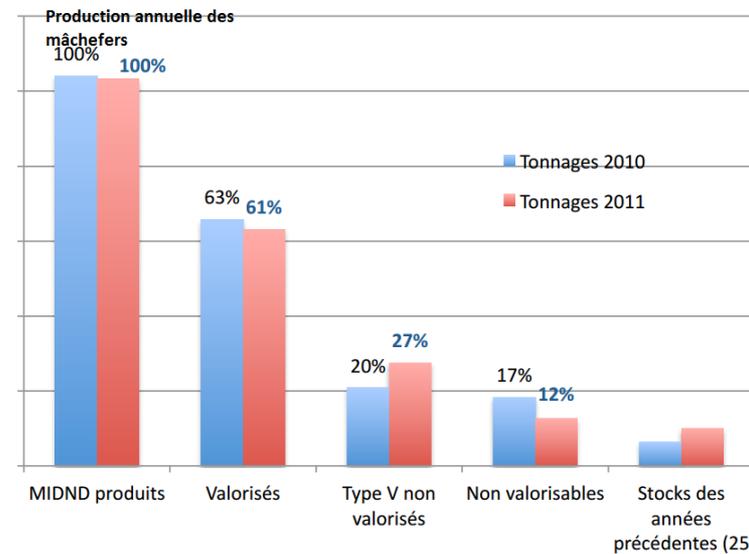
Reuse in Europe

- Road construction, embankment (France)
- Landfill construction (Italy)
- Concrete products (Netherlands)

Bottom ash in France (2012)

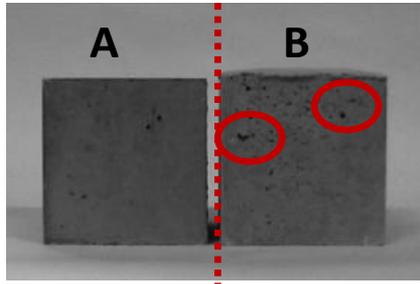
60% are beneficial used

- mainly road construction (~80%)
- recovery on landfills sites (<20%)
- **Testing in cement and concrete (0.2%)**



Problematic of research

Swelling and expansion phenomena



High porosity of sample B
(Bertolini et al, 2004)

**Presence of metallic particles
(Al, Fe, ...)**



Ettringite formation (Nielsen et al, 2009)



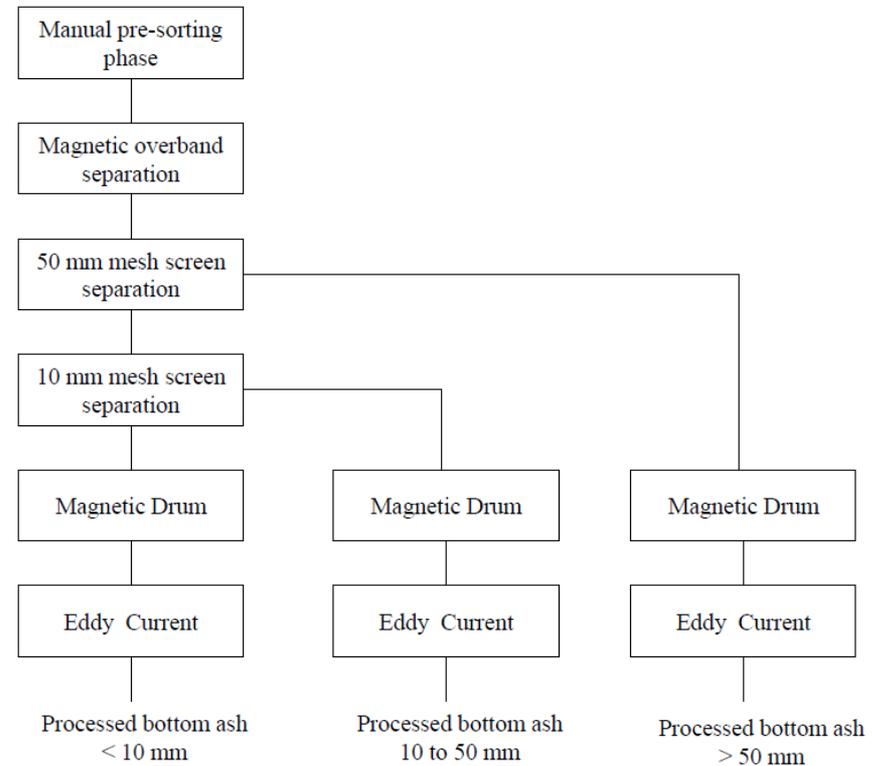
Formation of gel from oxidation of metallic aluminium
(Becquart, 2007)



Spalling on a face
(Müller and Rübner 2006)

Advanced technologies

- Dry separation process
(ADR Inashco, Granova)
- Wet separation process
(wet process, Indaver)



Conventional technologies for BA treatments

Objective of research

Substitution of natural sand by upgraded mineral sand fraction bottom ash in concrete applications

Physical characterization

European and french standards

Tests	Reference method
Grain size distribution	EN 933-1
Fine content	EN 933-1
Water absorption (24h)	EN 1097-6
Specify gravity	Helium pycnometer
Bulk density	EN 1097-3



Helium pycnometer



Water pycnometer test

Environmental characterization

- Leaching tests (EN 12457-2)
- L/S mass ratio equal to 10



Batch test

Chemical characterization

- X Ray Fluorescence (XRF)



Machine type S4 Pioneer from Bruker AxS

Mechanical characterization

• Preparation of mixture

- Mould samples 4 ×4 ×16 cm (EN 196-1)
- Substitution with BA 0-2 mm sand fraction
- Superplasticizer (0%, 1.5%; 2%, 3%) of cement mass
- Blast furnace cement (CEM III/A 42.5 N)
- Flow tests of each mixing



Flow test on shaking table

• Samples tests

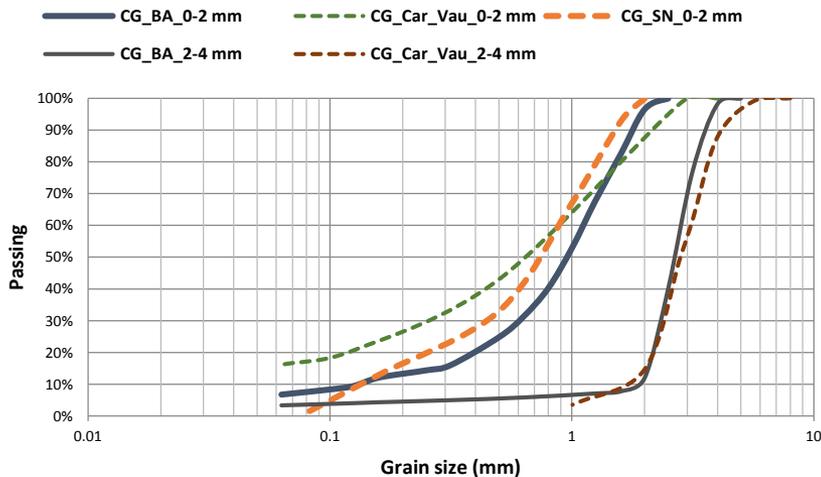
- Compressive tests with electro-mechanical press
- 14, 28 and 90 days of curing in water (20°C)



Instron press

Physical characterization

• Grain size distribution



Tests	BA 0-2 mm	BA 2-4 mm
Size curve	Well-graded	Uniform
Fine content	6.2%	3.2%
WA ₂₄	7.50%	5.40%
Specific gravity	2.61	2.61
prd	1.90	2.20

- BA curves are similar to natural sand curves
- Water absorption of BA is considerably higher than natural sand

According to XP18-545 French standards

BA 0-2 mm = cat. D ; BA 2-4 mm = cat. C ; natural sand = cat. A

Chemical characterization • BA 0-2 mm fraction

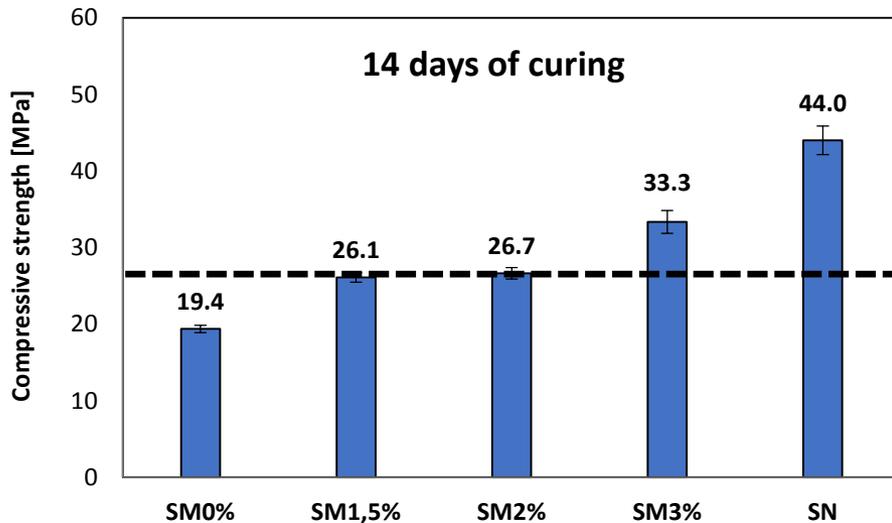
Composition	Wt (%)	Oxides	Wt (%)
Si	18.3	SiO ₂	39.1
Ca	16.2	CaO	22.7
Al	4.4	Al ₂ O ₃	8.3
Na	3.4	Na ₂ O	4.6
Fe	2.4	Fe ₂ O ₃	3.4
S	1.3	SO ₃	3.2
Mg	1.2	MgO	2.1
P	0.9	P ₂ O ₅	2.1

- SiO₂, CaO, Al₂O₃, Na₂O, Fe₂O₃ represent (~80%) in sampled BA
- SiO₂ represent > 95% in the standardized sand (EN 196-1)

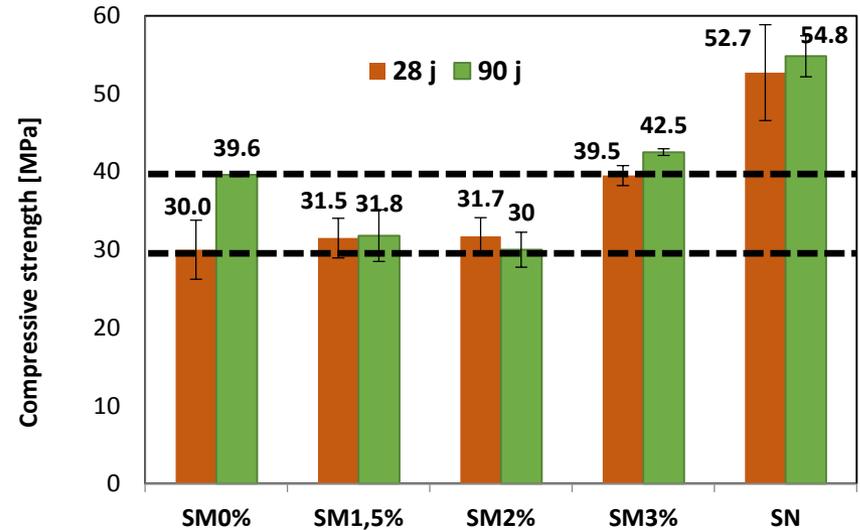
Environmental characterization • BA 0-2 mm fraction

Chemical component	Leaching values (mg/kg)	Threshold values French legislation	Threshold values European legislation
As	< 0.1	0.6	2
Ba	0.9	28 -56	100
Cd	< 0.002	0.05	1
Cr	< 0.01	1 - 2	10
Cu	1.0	50	50
Mo	< 0.1	2.8 – 5.6	10
Pb	< 0.04	1 – 1.6	10
Sb	< 0.1	0.6 – 0.7	0.7
Se	< 0.1	0.1	0.5
Chloride	2940	5 000 – 10 000	15 000

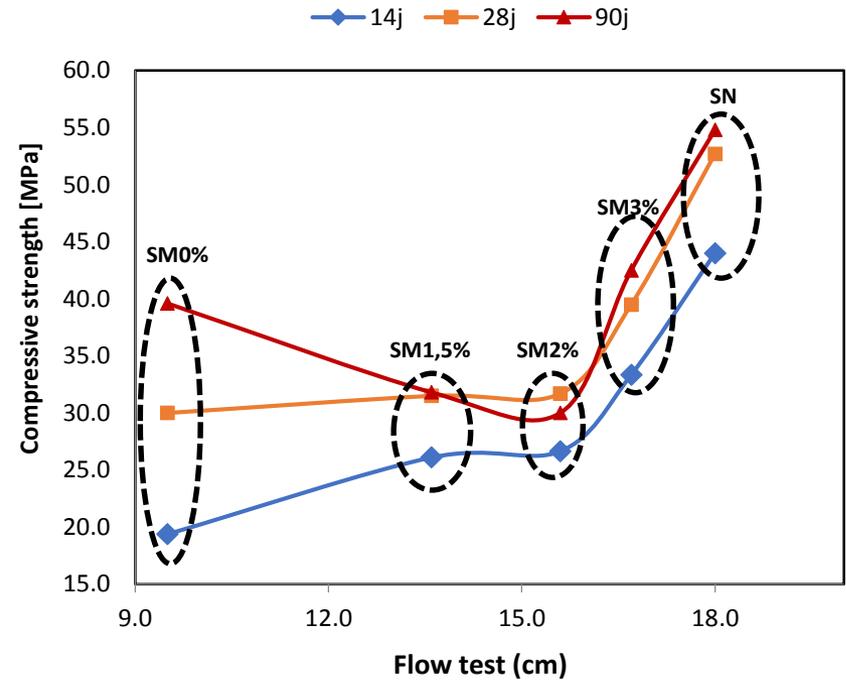
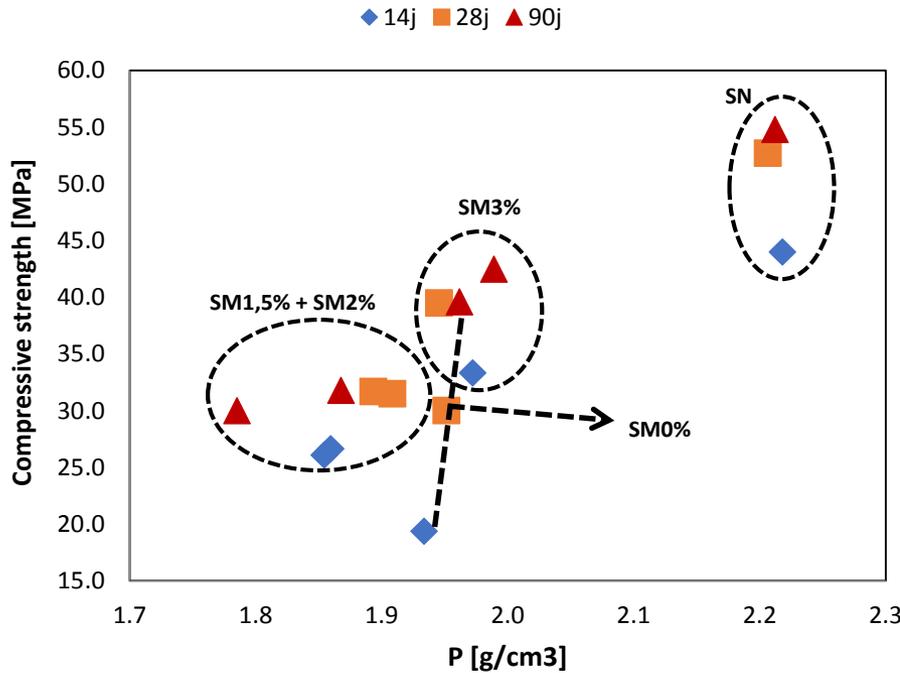
Mechanical characterization



- Decreasing of compressive strength SM0%
- CS of SM1.5% and SM2% are similar
- Increasing of CS with superplasticizer rate



- Good CS for different mixing (30 MPa)
- Linear trend observed at 14 d is different at 28 d and 90 d.
- At 28 d, SM0%, SM1.5% and SM2% are similar
- **At 90 d, SM0% is better than SM1.5% and SM2%**



- Unit weight of SM0% samples are higher than SM1.5% and SM2% samples at 90 d
- Unit weight of SN samples are higher than others mixing (SM0%, SM1.5-2% and SM3%)
- At 90 d, SM0% is 40 MPa with very low workability comparing to SM1.5% and SM2% with good workability

Conclusion

- Physical and chemical properties of sampled MSWI BA are similar to natural sands (except W_{Ab} equal to 7.50%)
- Main components of BA are SiO_2 , CaO , Al_2O_3 , Na_2O , Fe_2O_3
- **Sampled bottom ash are classified as wastes non-hazardous**
- Good mechanical resistances of mortar containing bottom ash
- Superplasticizer improve considerably the workability of mixing

Outlook

- Scanning electron microscope (SEM) have to carry out on moulded samples
- Environmental impact of an increased amount of superplasticizer in mortar and concrete applications
- Assessment of durability of samples (Shrinkage, swelling, chloride attack)
- **Partial substitution of natural sand (V/V) by Upgraded mineral sand fraction (25%, 50% and 75%)**



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Transforming wastes into raw materials for the future

Thank you

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 Promoting Policies and Practices for Sustainability



Global Alliance
 for Buildings and
 Construction