Vitrification and reuse of municipal solid waste incinerator and biomass ash

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Abstract

Incineration of municipal solid waste has proven to be of strategic value in the waste management process as it combines the advantage of possible energy production with a volume reduction of waste up to 90%. However, the by-products of **municipal solid waste incinerators** (MSWI), bottom and fly ashes, need to be adequately treated before landfilling or reuse to avoid the leaching of heavy metal ions and consequent pollution of ground water resources.

The aim of this work is a contribution to the currently on-going efforts to find an effective and environmentally safe way of using vitrified bottom ash from municipal solid waste incinerator.
The results of this first work demonstrate that **vitrified bottom ash (VBA)** can be used as filler, sand and aggregate in concretes or bituminous mixtures, saving several million tons per year of natural materials and dramatically reducing landfill-related problems.

Together with the reuse of MSWI ash, also the reuse of **biomass combustion ash** is an issue, due to the increasing use of biomass in large power plants. In Italy, biomass ash is generally disposed in landfills. A recent project, supported by Italian Agriculture Ministry and the European Union's Seventh Framework Programme, is focused on the study of biomass combustion ash reuse in construction materials, as an alternative to landfill disposal. The aims and some preliminary results of this second project will be presented.

VBA in mortars and concrete

Two tons of MSWI bottom ash were vitrified at EffeTre S.p.A., Murano-Venice Italy, by melting the bottom ash in a glass-melting furnace powered by 70 m^3 CH_4 per h (MT, Italy), without using any additives.

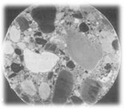
Vitrified bottom ash (VBA) from MSWI

Chemical analysis of VBA, wt%

Oxide	Wt-%
SiO_2	51·7
Al_2O_3	10·9
Fe_2O_3	5·8
MnO	0·1
CaO	16·2
MgO	4·1
Na_2O	6·9
K_2O	1·6
TiO_2	0·7
BaO	0·2
ZnO	0·2
SO_3	0·3
P_2O_5	0·7
Others	Balance

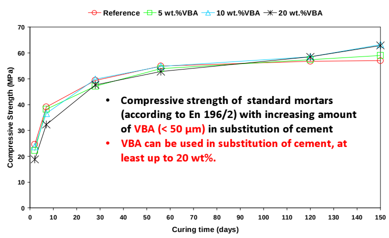
Thermal and mechanical properties of VBA

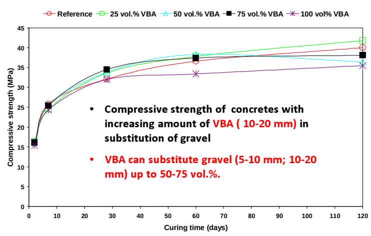
Young modulus, GPa	80±1
Vickers Hardness, GPa	6±0·1
Indentation Toughness, MPa $m^{-1/2}$	0·5±0·2
Thermal expansion coefficient, 10^{-6} K^{-1}	9·6 (100–500°C)
Density, g cm^{-3}	2·71±0·02



Concrete sample with VBA aggregates

- **Vitrified bottom ash (VBA)** was ground and sieved to different dimensions (ranging from 50µm to 20 mm) and used as filler, sand, or aggregate for concrete.
- Samples were characterized via slump tests (UNI 9418), alkali-silica reactivity (UNI 8520/22 and ASTM C 298), and compression strength tests (UNI 6132, 6132/72, 6686/72), and compared to reference samples obtained without vitrified bottom ash.
- **No alkali-silica reactions** or other detrimental reactions were observed after 2 years in VBA containing concrete and Pozzolanic activity resulted positive.



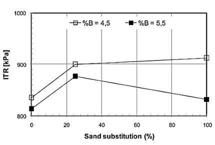


- **VBA can be used in substitution of cement** (<50 µm or <90 µm), at least up to 20 wt.%. After 150 d, the compression strength of samples seems unaffected by adding up to 20 wt.% VBA as a filler in mortars.
- VBA cannot be used to substitute natural sand (<5 mm) unless low strength applications are required; this grain size (<5 mm) is the most unsuitable for VBA because it cannot act as a reinforcing second phase in compression because of the poor cohesion between the smooth surface glass sand (large surface area) and the cement paste.
- **VBA can be used to substitute gravel** (5–10 mm; 10–20 mm) up to 50–75 vol.%. VBA of this size can fully exploit its reinforcing role as a second phase in concrete.

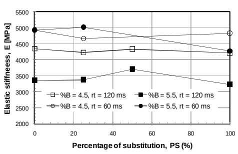
VBA in bituminous mixtures

- The experimental plan was focused on the effects associated to variations of both the binder content (4.5–5.5%) and the percentage of sand substitution with vitrified MSWI ashes (0–100%).
- The investigation was carried out by considering performance related compaction, volumetric and mechanical properties, which were assessed in the laboratory by employing a number of different characterisation techniques.

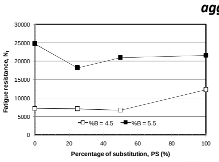
Bituminous mixture sample with VBA aggregates



Indirect tensile strength of the bituminous mixtures



Elastic stiffness of the bituminous mixtures



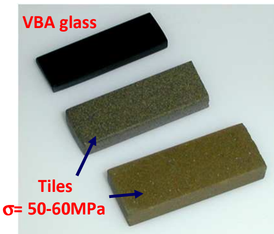
- **Mechanical properties comparable to the reference mixtures** (Sand substitution Ss = 0%)
- Appropriate mix design may lead to a further enhancement of mechanical performance

Selected fractions of vitrified bottom ash (retained on the 0.4, 0.18 and 0.075 mm sieves)

VBA as raw material for tiles

Vitrified bottom ash (VBA) and corundum-based waste material (from an aluminum alloy manufacturer) or kaolin-based waste material were sintered to obtain glass ceramic tiles.

- The bending strengths and the Young's modulus of the materials sintered at 950°C are very good and sufficiently high to **satisfy the requests for ceramic wall tiles** (i.e. bending strength > 12 MPa).
- The water absorption of the tiles sintered at 950°C corresponds to tiles of BIb type in UNI EN 87 ceramic tile classification.

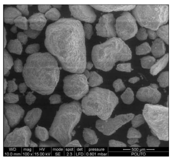


Tiles from VBA sintering

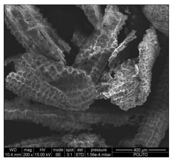
Ash from biomass combustion

The ashes used in this study were collected from twelve different power plants, eleven in Italy and one in Sweden (Lantmännen Energi, Skurups Fjärrvärme). They are by-products from the combustion of several different biomasses including woodchips, shells, rice husk, RDF (Refuse Derived Fuel), straw, bark and sludge.

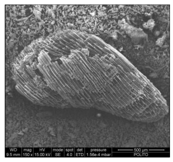
- **Woodchips based ash** has high content of CaO that may have a good effect on the stability of asphalt mixtures at the mastic (bitumen+filler) and slurry scale. Preliminary tests showed that it is absolutely **not acceptable as Portland substitute**.



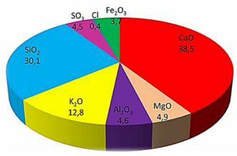
Ash from combustion of shells



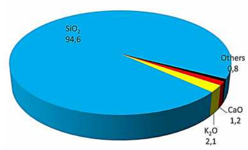
Ash from combustion of rice husk



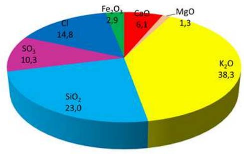
Ash from combustion of woodchips



Average composition of ash from woodchips combustion (wt%)



Average composition of ash from rice husk combustion (wt%)



Average composition of ash from straw (wt%)

In order to obtain an homogeneous material, biomass ash was vitrified without using any additives at different temperatures (from 1200°C to 1450°C).

Thermal and mechanical properties of vitrified woodchips-based ashes	
Young modulus, GPa	90±5
Vickers Hardness, GPa	7.3±0.4
Thermal expansion coefficient, 10^{-6} K^{-1}	10.4 (200-400°C)
Density, g cm^{-3}	2.7±0.2

Bituminous mixtures

- Biomass ash is a valuable alternative to traditional fillers in asphalt mixtures, mainly due to its low organic and clay content.
- A milling and/or sieving process is necessary to reach optimal grading, since most of the ashes do not respect the EN 13043 size distribution limits.
- Geometrical, physical and chemical characteristics of biomass ash may vary during the year depending on collection period.

Glass from woodchip ash vitrification

- Biomass ash is characterized by high porosity (measured through Rigden Voids test) which may exceedingly stiffen the bitumen.
- **Leaching tests** performed on the ashes in their original state showed that the release of pollutants of **most of the ashes exceeds the Italian limits for environmental reuse**. However, when they are used as filler in asphalt mixtures, the coating role of the binder may reduce the amount of released pollutants.

Conclusions

- Vitrification of ash from MSWI and biomass combustion offers the advantage of a complete inert and homogeneous material.
- The results of this work demonstrate **that vitrified bottom ash (VBA) can be used as filler, sand and aggregate in concretes or bituminous mixtures**, saving several million tons per year of natural materials and dramatically reducing landfill-related problems.
- **Biomass ash**: experimental results show a wide range of values for almost all the investigated properties and low correlation with biomass type. When used as filler in asphalt mixtures, most of the ashes do not respect acceptance limits for grading: it can be concluded that processing the raw material before its re-use is necessary. However, the effectiveness of these treatments and the low content of organic matter and harmful fines in the ashes suggest that **ash from biomass combustion may be considered as a replacement for filler in asphalt mixtures**.

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Acknowledgements

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