Engineered Stone Made of Modified BOF Slag

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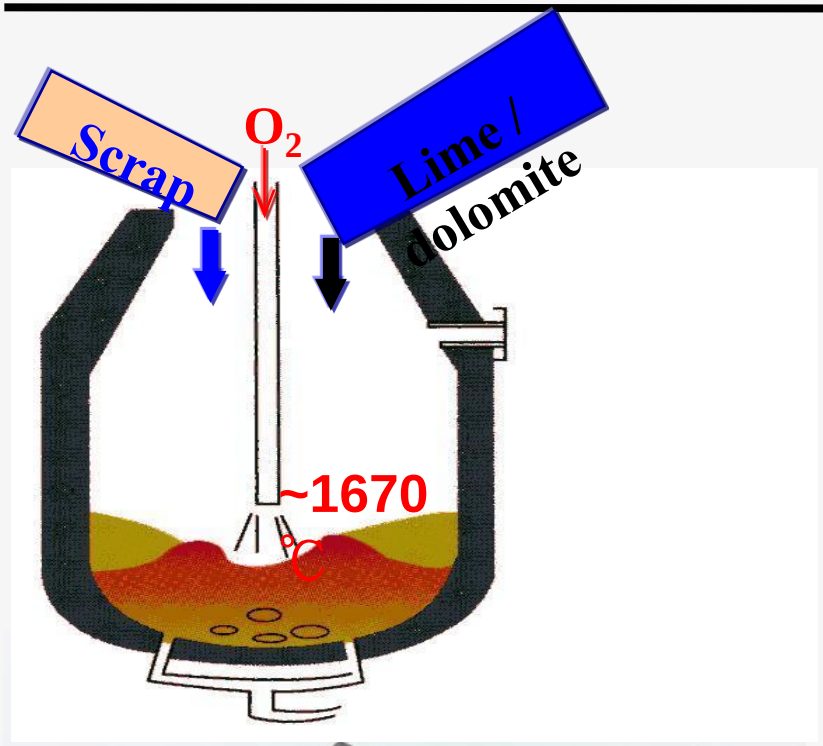
Introduction



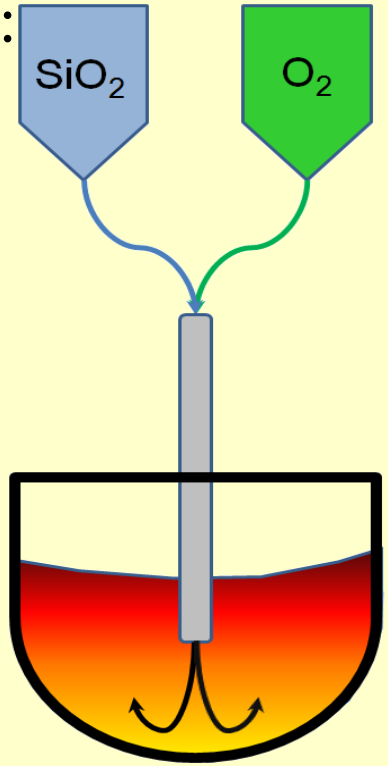
$$MgO + H_2O \rightarrow Mg(OH)_2$$

$$CaO + H_2O \rightarrow Ca(OH)_2$$

Volumetric expansion

The Hot Stage BOF Slag Modification and Its Processing

Principle:



※**Reaction**:

4 FeO + O_2 → 2Fe_2O_3 △H=-531 kJ/mol.

2 CaO(free) + SiO_2 → 2CaO·SiO_2

2 CaO(free) + Fe_2O_3 → 2CaO·Fe_2O_3

Methodology:

1.Molten slag

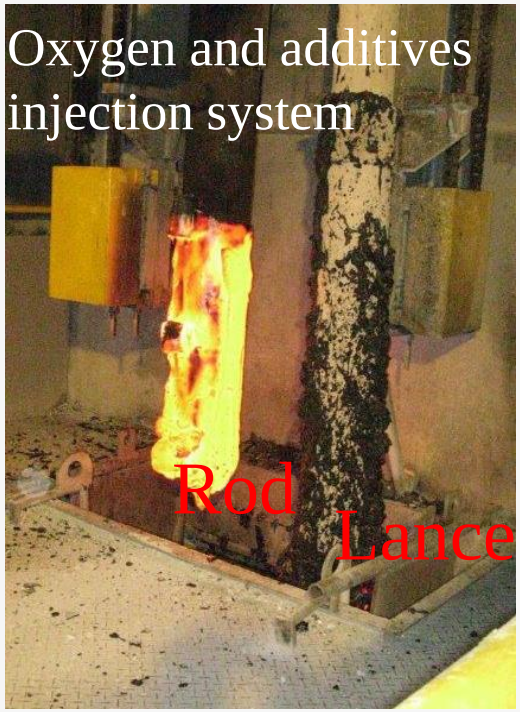
2.Blow oxygen into molten slag for getting heat generated from the oxidation of iron

3.Inject silica to react with f-CaO/MgO, so that transform them to silicates.

4.f-CaO reacts Fe_2O_3 to form $2CaO{\cdot}Fe_2O_3$.

☛f-CaO/MgO is remelted completely.

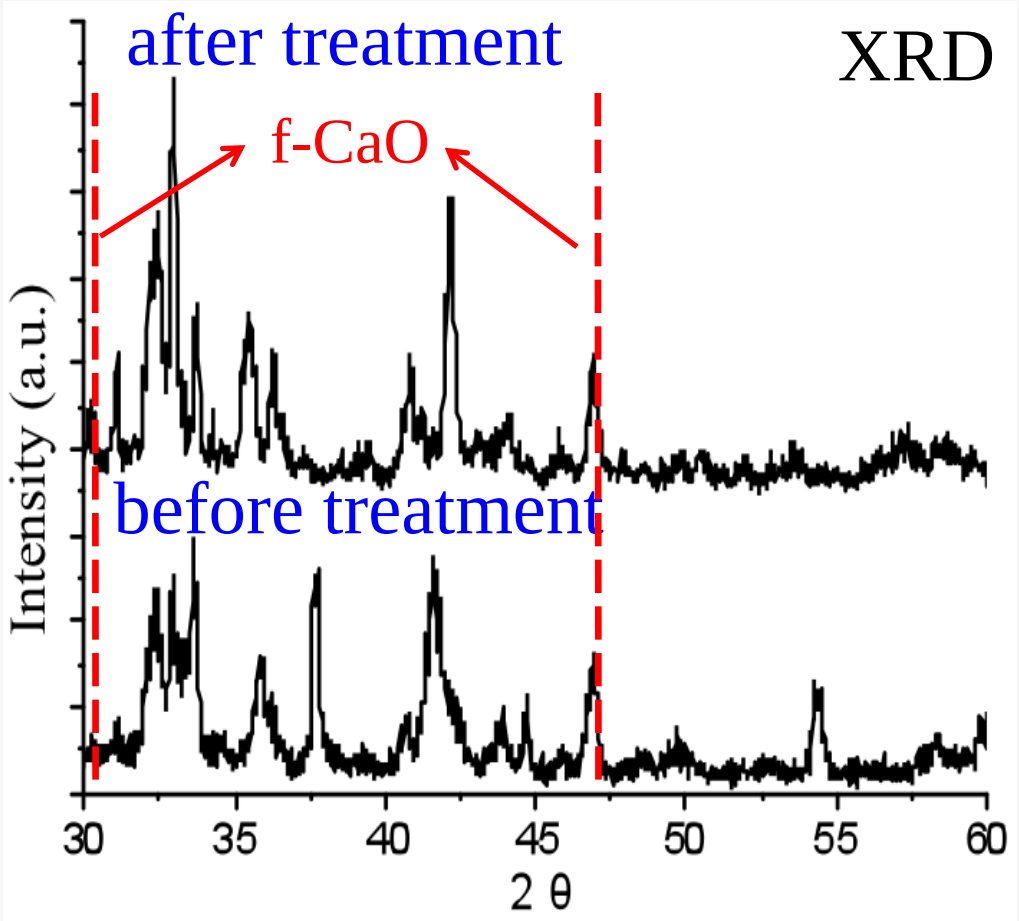
The Hot Stage BOF Slag Modification and Its Processing



The Property and Quality of the Modified BOF Slag

Before treatment

After treatment



After modification

Volumetric expansion <0.4%

The Property and Quality of the Modified BOF Slag

Comparisons of the properties of natural aggregates, BOF slag and modified BOF slag

Materials	specific gravity	water absorption (%)	loss of Los Angeles abrasion (%)	loss of soundness (%)	Mohs hardness	Volumetric expansion (%)
Natural aggregates	2.64	1.7	27.2	2.9	~4.0-5.0	~0
BOF slag	3.40	1.8	11.4	1.3	~5.0-6.0	3-4%
Modified BOF slag	3.47	1.6	10.0	~0	~5.5-6.5	<0.5%

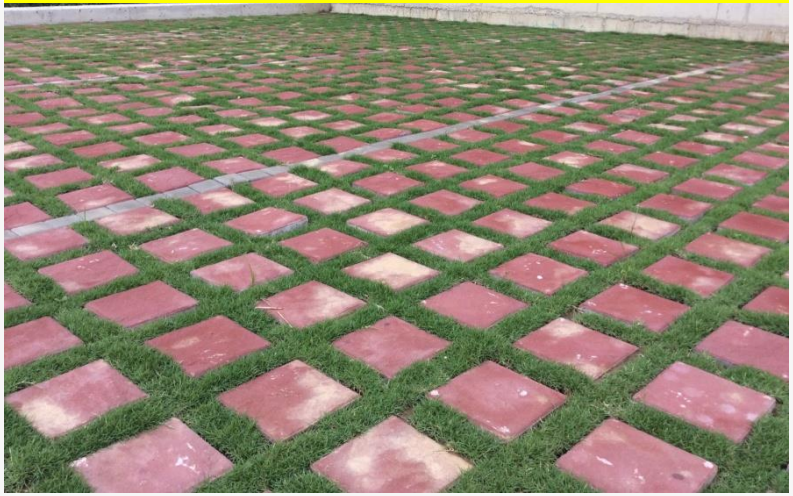
The utilization of modified BOF slag in engineering materials

- Asphalt Concrete pavement
- Pavement bricks
- Concrete products
- Railway Ballast

The Utilization of Modified BOF Slag

Porous AC Freeway

Grass Bricks



Concrete Product (Tetrapods)

Railway Ballast

The Utilization of Modified BOF Slag – Engineered Stone

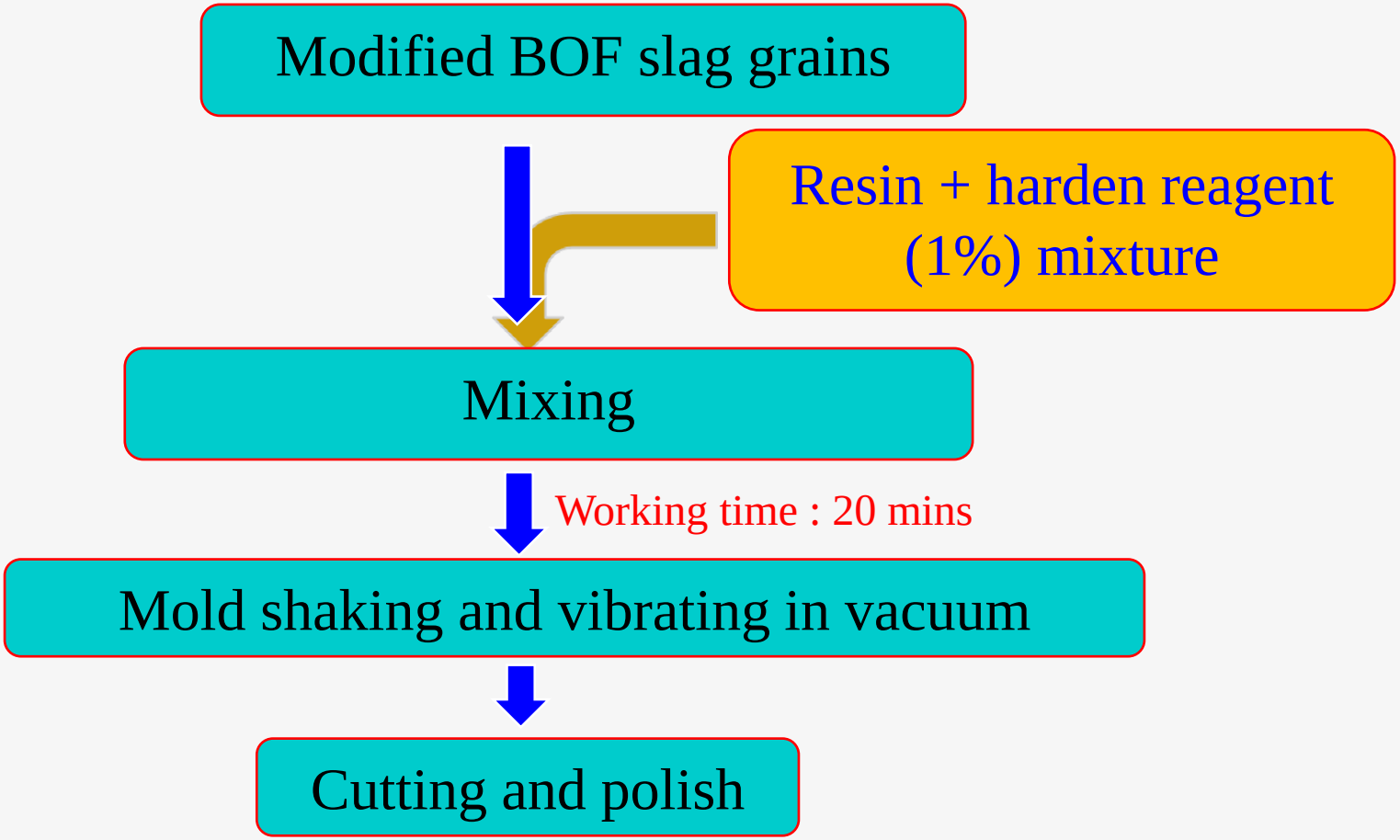
High Value-added Products

Engineered Stone

Artificial marble / granite products : 30 € (900 cm^2)

The Utilization of Modified BOF Slag – Engineered Stone

Production of Engineered Stone Made of **Modified BOF slag** and **Resin**



The Utilization of Modified BOF Slag – Engineered Stone

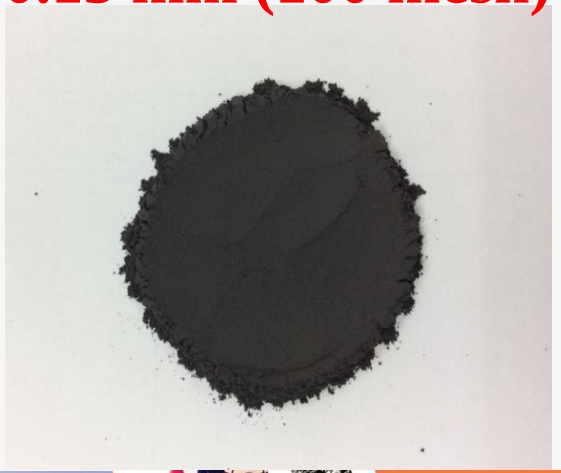
Size of raw materials (modified BOF slag)

≦ 5 cm

≦ 1 cm

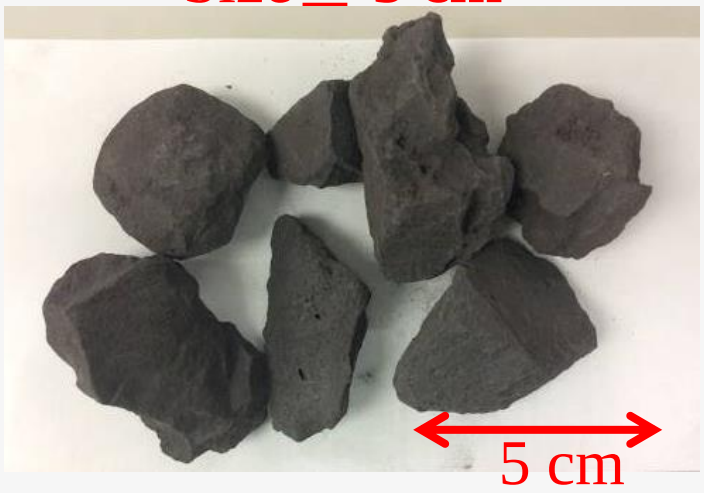
≦ 1.7 mm

≦ 0.15 mm (100 mesh)



The Utilization of Modified BOF Slag – Engineered Stone

Size≦ 5 cm



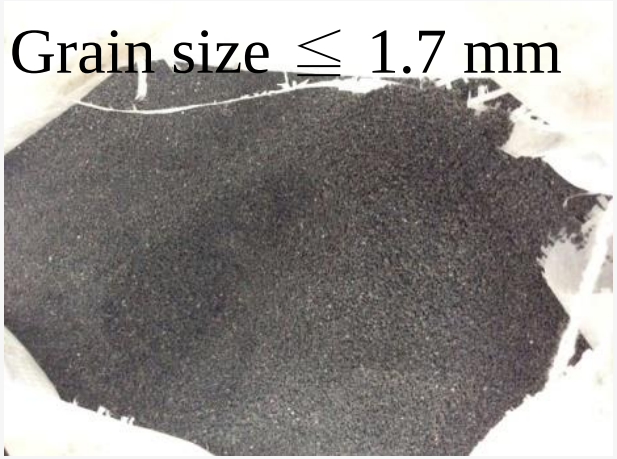
Porous surface

Larger modified BOF slag have more defects than smaller ones, which show apparent pores on the surface

Choosing smaller grains

The Utilization of Modified BOF Slag – Engineered Stone

Grain size ≦ 1.7 mm



Size distribution	Wt. %
1mm < x < 1.7mm	39.5 %
0.4mm < x < 1mm	24.7 %
0.3mm < x < 0.4mm	19.8 %
x < 0.15 mm	16.0 %

Modified BOF slag /Engineered stone = 95.2%

The Utilization of Modified BOF Slag – Engineered Stone

Scale up : Making 100 × 100 cm^2 engineered stone

The Utilization of Modified BOF Slag – Engineered Stone

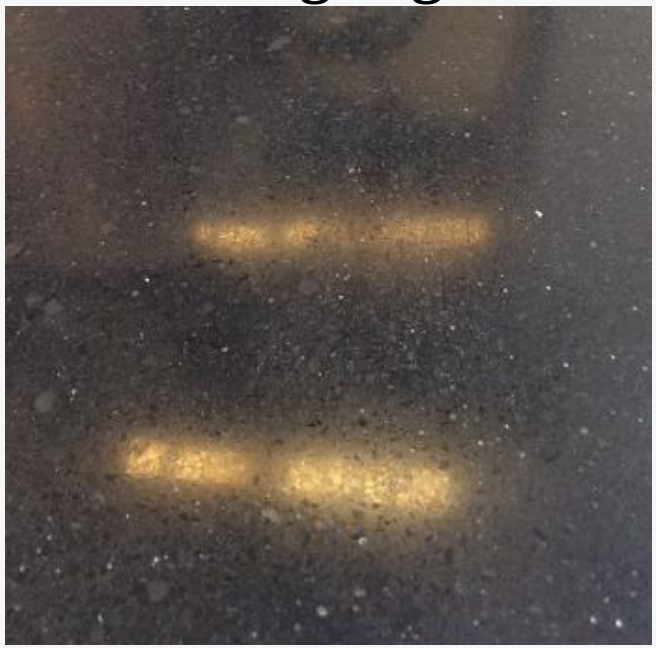
The final product (area: 100 × 100 cm^2)

The Utilization of Modified BOF Slag – Engineered Stone

Comparisons of commercial product and modified BOF slag engineered stone

Commercial product

Modified BOF slag engineered stone



Properties	Values	Commercial Product
water absorption (%)	0.3%	0.2%
flexural strength (Mpa)	41.6	14.4
compressive strength (Mpa)	121.7 ± 14.8	130

The Utilization of Modified BOF Slag – Engineered Stone

Toxicity characteristic leaching procedure Test

Materials/ Standard	TCLP (mg/L)									
	As	Hg	Ba	Cd	Cr	Cu	Pb	Se	Cr(VI)	pH
Modified BOF slag	ND	ND	ND	ND	ND	ND	ND	ND	ND	12
Modified BOF slag Engineered Stone	ND	ND	ND	ND	ND	ND	ND	ND	ND	11.4
Taiwan EPA Standard	<5.0	<0.2	<100	<1.0	<5.0	<15.0	<5.0	<1.0	<2.5	12.5

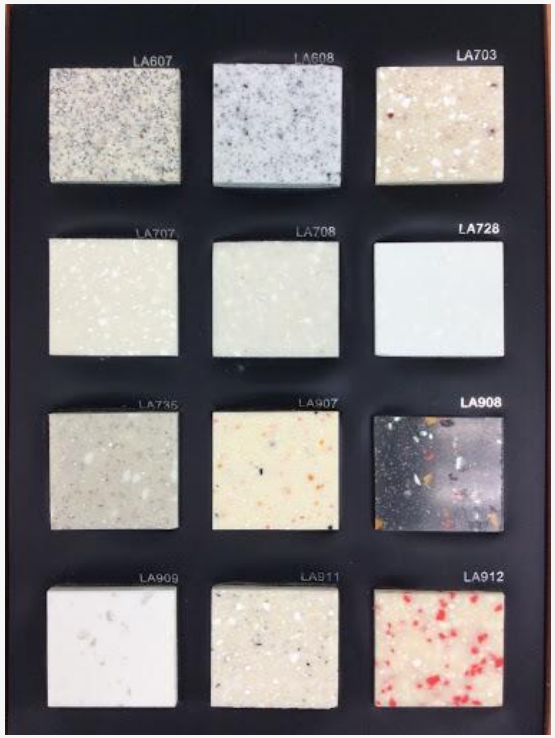
The Utilization of Modified BOF Slag – Engineered Stone

The cost and profit

Products / Cost breakdown	Engineered stone table
	cost(euros/m^2)
Crushing	7.14
Resin	175.92
Molding	30.92
Cutting and Polish	74.20
Market price	309.17
Net profit	20.99

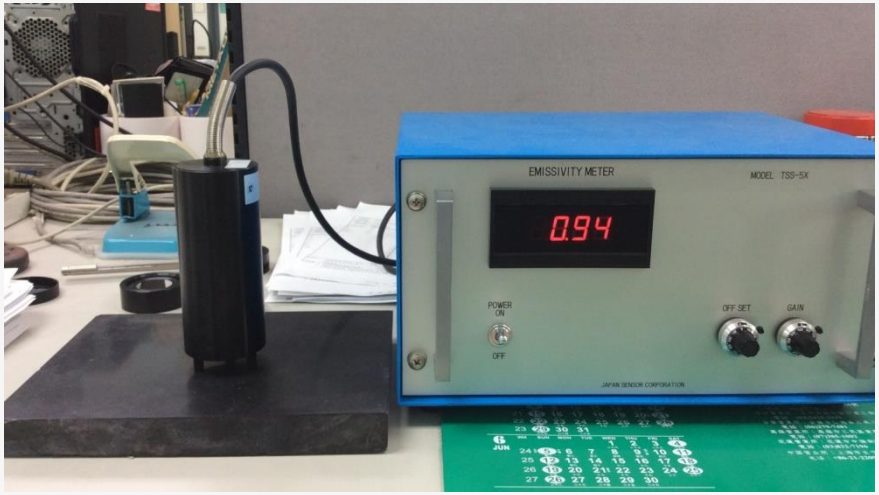
The Utilization of Modified BOF Slag – Engineered Stone

Future work: colorful engineered stone



The Utilization of Modified BOF Slag – Engineered Stone

Surprising finding: High Far Infrared Emissivity at Room Temperature



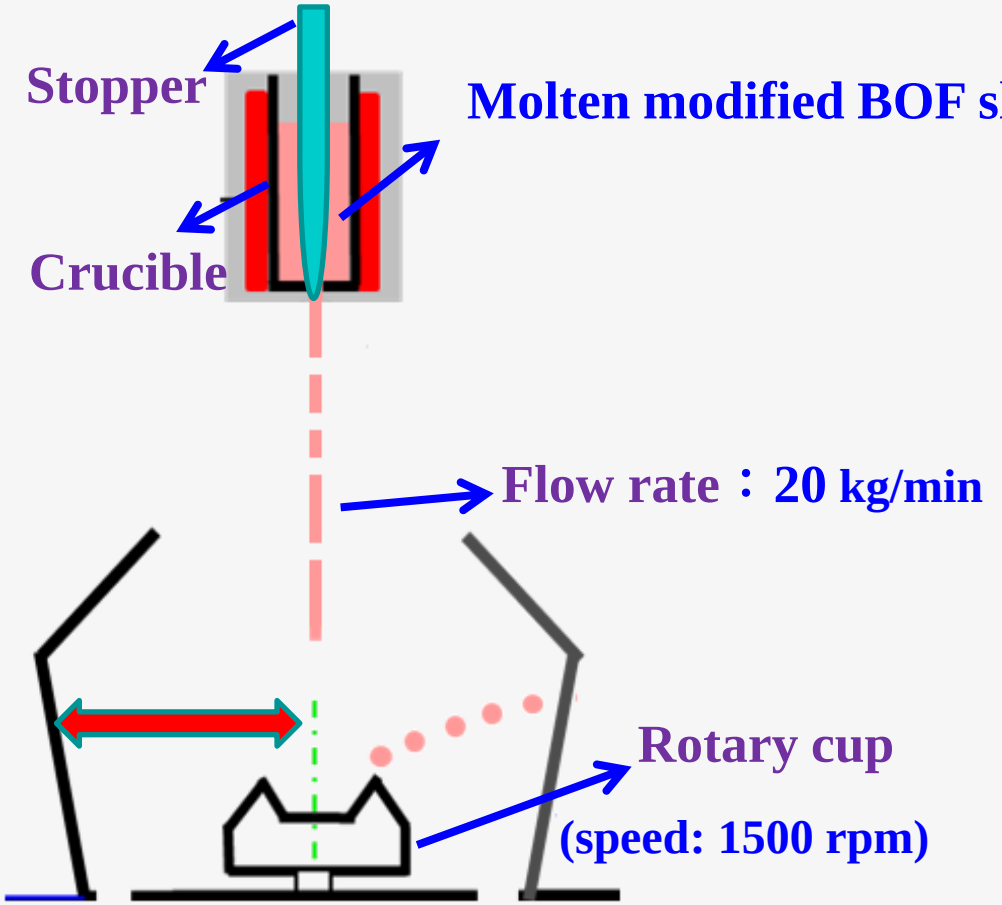
$\varepsilon_{2\text{-}22\mu m}$ (25℃) = 0.91±0.3

Wine aging

Fruit ripening

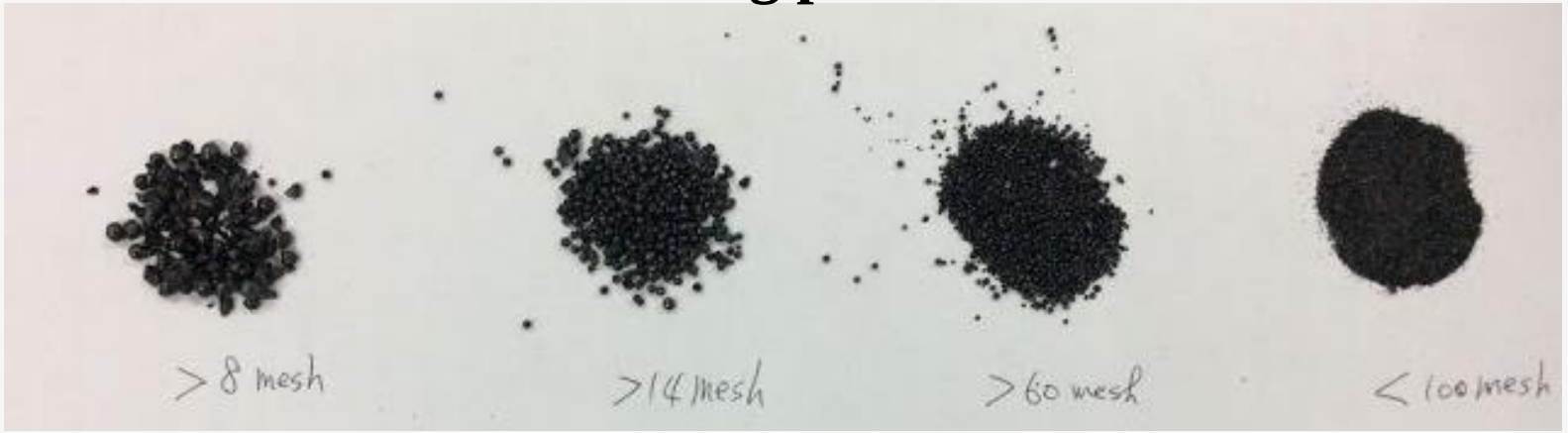
The Utilization of Modified BOF Slag – Engineered Stone

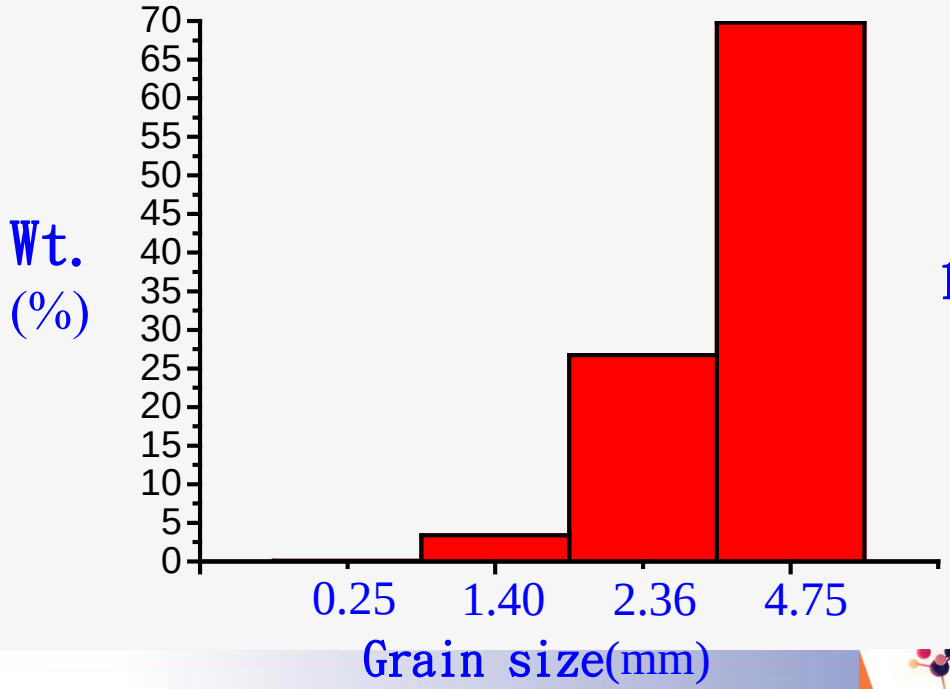
Future work: instead of crushing, using granulated tech



The Utilization of Modified BOF Slag – Engineered Stone

Granulated modified BOF slag product





100% grains < 4.75mm

Summary

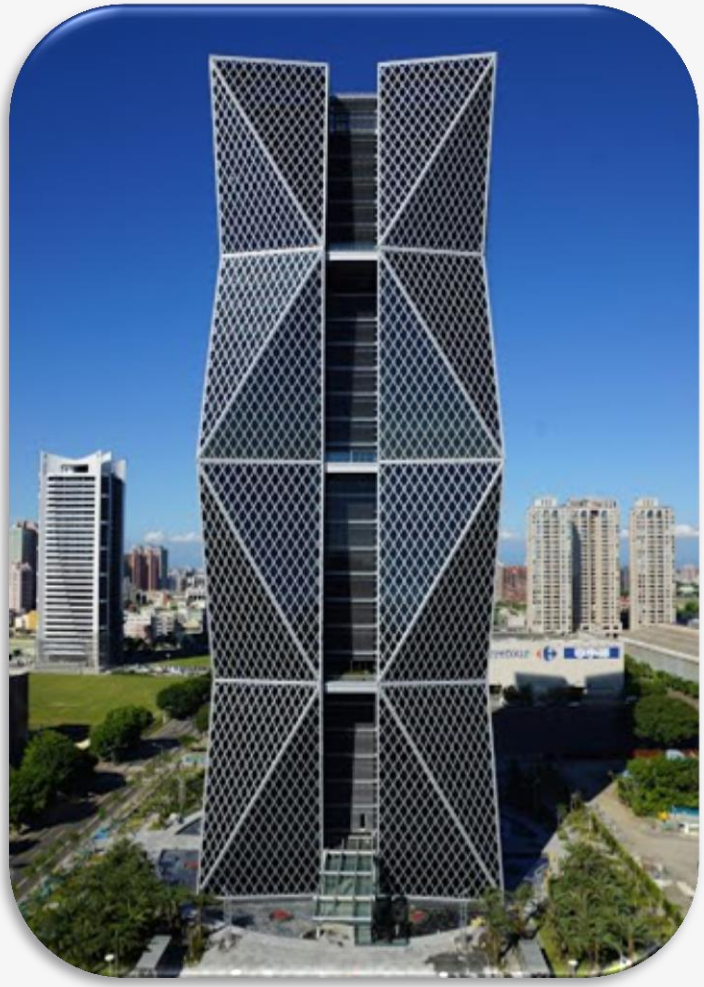
- The hot stage BOF slag modification process can produces high quality of volumetric stable aggregates with excellent physical properties.

- The engineered stone(with area up to $100 \times 100\ cm^2$) consisted of 95.2% modified BOF slag presents (particle size < 1.7mm) a compact structure with its water absorption(<0.3%), compressive strength (121.7 MPa), as well as flexural strength(41.6 MPa) are similar or even superior to commercial ones, which indicates modified BOF slag is a potential material for the production of high value-added products such as engineered stones.

Summary

Toward the Development of High Value-added Products

Thanks for your attention.



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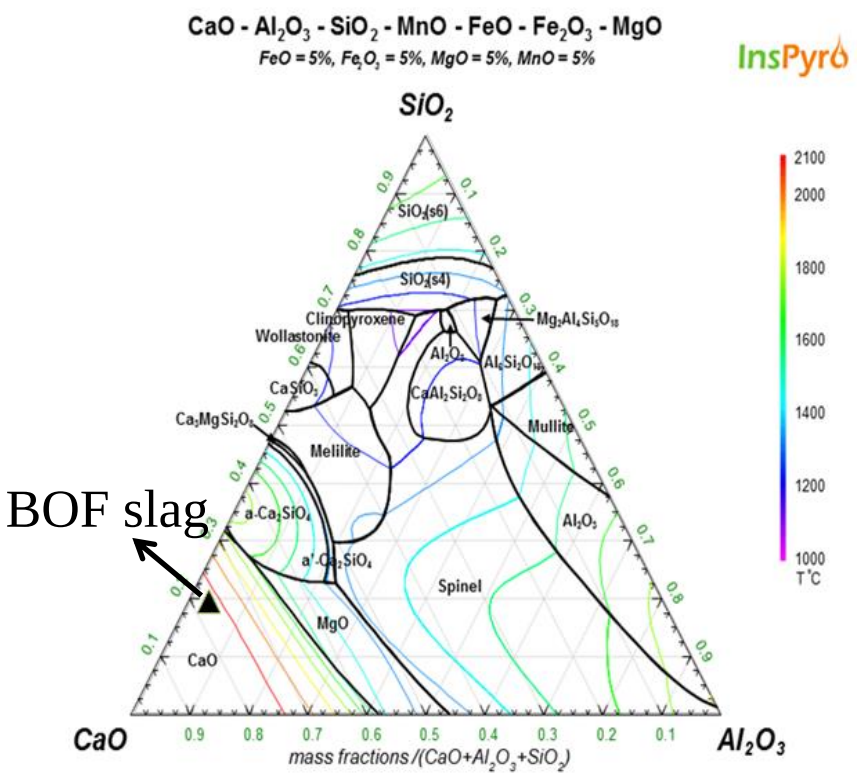
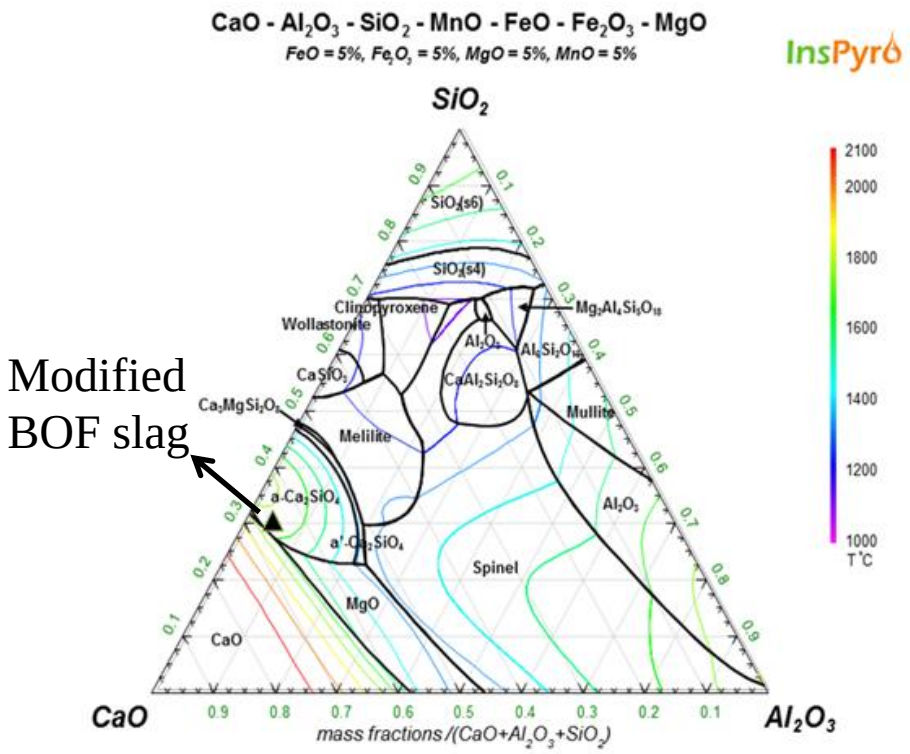
The Phase Diagram of BOF slag and the Modified BOF Slag



BOF slag

CaO	SiO2	Al2O3	MgO	FeOx	MnOx	CrOx	Na2O	P2O5
44.91	11.12	1.87	6.44	31.08	3.64	0.21	-	0.73

	VISCOSITY	%SOLID	LIQUIDUS	SOLIDUS
1000 °C	Out of rar Pa.s	100.0	1781 °C	1121 °C



Modified BOF slag

CaO	SiO2	Al2O3	MgO	FeOx	MnOx	CrOx	Na2O	P2O5
40.42	18.44	2.29	5.52	28.13	3.13	0.21	-	1.88

	VISCOSITY	%SOLID	LIQUIDUS	SOLIDUS
1600 °C	0.09 Pa.s	0.0	1487 °C	1171 °C

Comparisons of the properties of artificial marble, artificial granite and modified BOF slag

Materials	Mohs hardness	Compressive strength
Artificial Marble	4	60 MPa
Artificial granite	6	100 MPa
Modified BOF slag	~5.5-6.5	160 MPa

Blind Drinking of Sorghum Wine

Number of Participants :16

	Original	FIR at RT for 6h	FIR at 60°C for 6h	Commercial Ceramics(6h)
Spicy Scale	45	43	39	35

Spicy ——— Smooth

Analytical data	Original	FIR at RT for 123h	FIR at 60°C for 123h	Commercial Ceramics (123h)
Aldehyde conc. (μM)	66.8	60.3	59.0	52.3