

Slag for Cement Making USA Experience

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Bulk Materials International Co.

- **Leading supplier of products and services to the cement industry since 1986.**
- **Total Annual Sales \cong 3.5 Million Tons**
- **Slags \cong 2.0 Million Tons**
 - Granulated Blast Furnace Slag
 - Steel Slag
 - Others

Dedicated to promoting the use of slag in the cement industry.

What is Slag?

- “Slag” refers to any number of byproducts from the steel making process.
- It was once discarded as a useless material and accumulated in landfills.

Slag is now recognized as a valuable material.

Types of Slag

- **Granulated Blast Furnace Slag (GBFS)**
- **Air Cooled Blast Furnace Slag**
- **Basic Oxygen Furnace Slag (BOF)**
- **Electric Arc Furnace Slag (EAF)**

Benefits of GBFS

- **Reduced Permeability Results in Better Concrete**
- **Improved Compressive Strength**
- **Improved Flexural Strength**
- **Lower Susceptibility to Water Ingress**
- **Improved Resistance to Sulfate Attack**
- **Improved Resistance to Alkali-Silica Reaction**

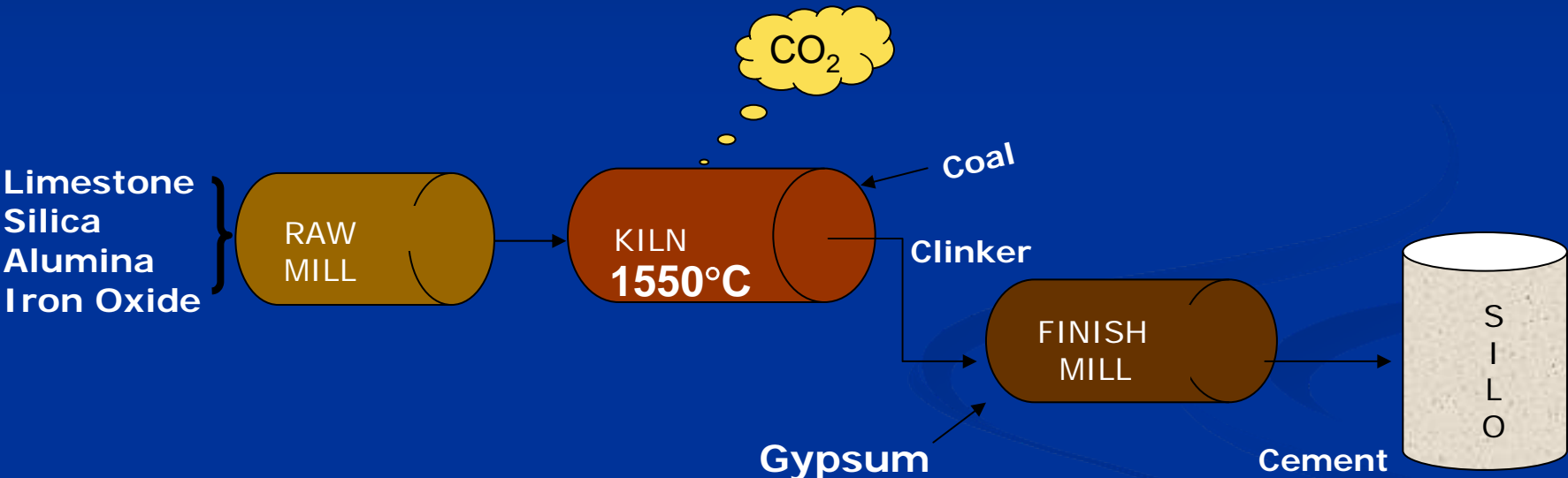
Benefits of GBFS

- **Improved Resistance to Sulfate Attack**
- **Improved Resistance to Alkali-Silica Reaction**
- **Improved Resistance to Chloride Penetration & Carbonation**
- **Ideal For Mass Concrete Pours & Warm Climates**
- **Slower Setting Time For Easier Workability & Finishing**

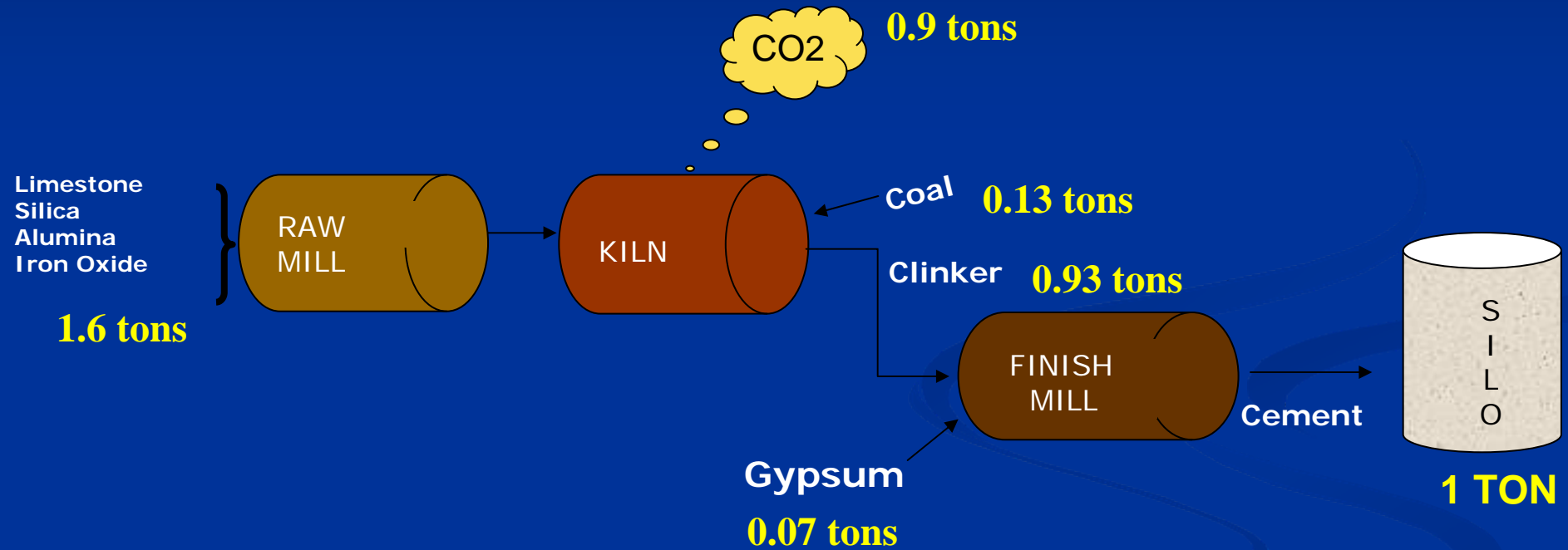
The Benefits of Using Slags from the Steel Industry to Manufacture Portland Cement

- Increased production without expansion
(*no capital investment*)
- Reduction of CO₂ Generation

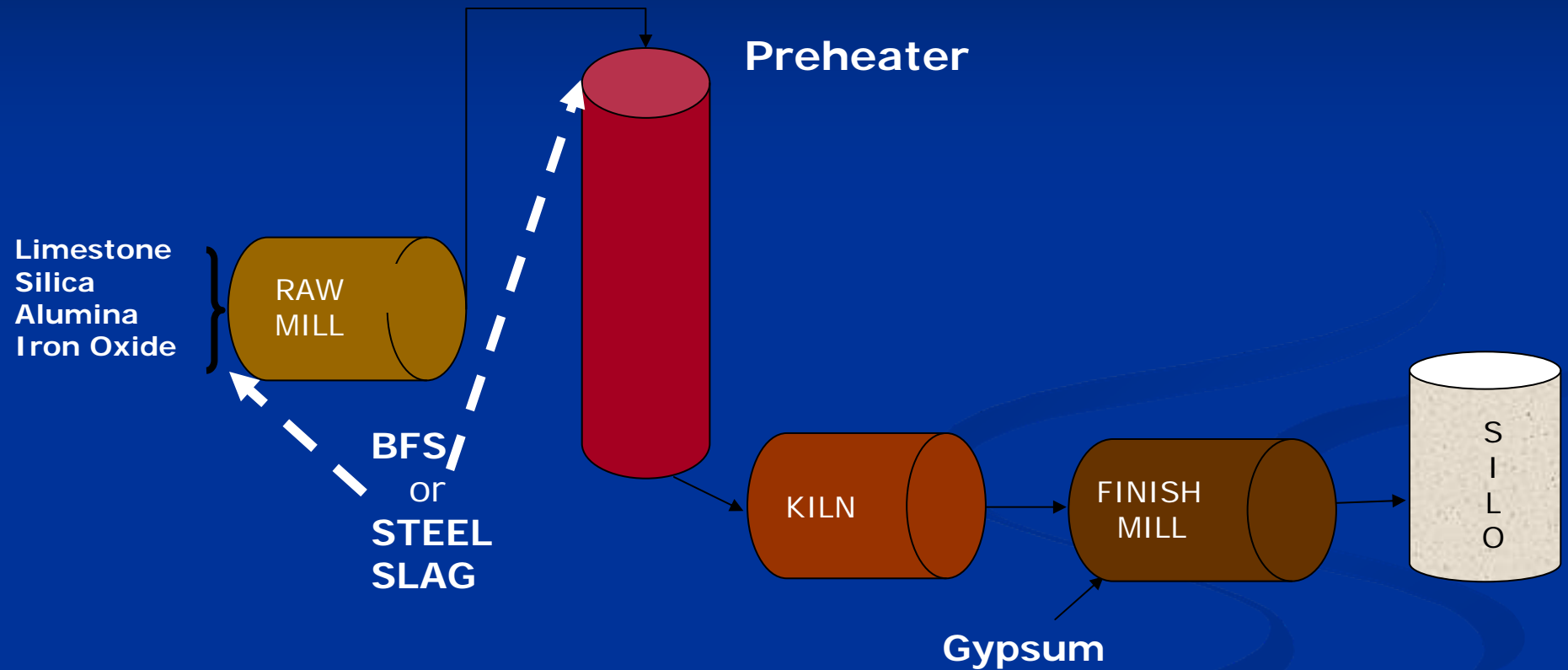
HOW PORTLAND CEMENT IS MADE



PORTLAND CEMENT MANUFACTURING



SLAG AS A RAW MATERIAL



BFS = Blast Furnace Slag

USA Experience

- Slag is used when the plant needs more production
- There is no economic incentive to use slag as a raw material solely for the purpose of CO₂ reduction
- A significant number of plants are using slag as a raw material
- Three actual cases:

Case #1

- Plant "A" uses blast furnace slag as a raw material on a routine basis.
- This is a preheater plant with an annual cement capacity of ~ 650,000 tons.
- Based on the amount of extra clinker the plant needs to meet their cement sales, the slag addition ranges between 4% and 10%.
- The highest slag usage during any month has been 8.5%.
- The slag addition is limited by its MgO content.

Case #1

Slag Chemistry

SiO₂	32
Al₂O₃	10
Fe₂O₃	1.7
CaO	45
MgO	7
SO₃	1.8
K₂O	0.3
Na₂O	0.3
TiO₂	0.6
MnO	0.2
Cr₂O₃	0.04
LOI	1

Case #1

- Five component mix when slag is used.
- The increase in clinker production is directly proportional to the amount of slag used. For example, 7% slag usage results in 7% more clinker. This percentage exactly matches the change in the kiln feed LOI.
- Fuel savings is ~ 90% the slag addition. For example, a 5% slag addition results in a 4.5% fuel savings.

Case #1

Economics: 4% Slag Addition Compared to Imported Clinker

Total Slag (4% of 900,000 tons of kiln feed)	36,000
Slag cost @ \$30/ton	\$1,080,000
36,000 tons slag yields 36,000 tons of clinker	
Fuel, electricity, handling=\$10/ton	\$360,000
Total cost for the additional clinker	\$1,440,000
Imported clinker cost is \$70/ton	
\$70/ton x 36,000 tons	\$2,520,000
\$30/ton Savings compared to imported clinker	\$1,080,000

Case #1

Economics: Increased profit due to Cement Sales from 4% Slag Addition

Total Slag Added, tons	36,000	
Increased Clinker Production, tons	36,000	
Increased Cement Production, tons	38,000	(5% gypsum)
Revenue from Increased Cement @ \$90/ton	\$3,420,000	
Clinker Cost	\$1,440,000	
Gypsum Cost @ \$30/ton	\$60,000	
Electricity, Grinding Aid, Handling @ \$8/ton	\$304,000	
Profit	\$1,616,000	

Case #1

Economics: 8.5% Slag Addition Compared to Imported Clinker

Total Slag	76,000	(8.5% of 900,000 tons of kiln feed)
Slag cost @ \$30/ton	\$2,280,000	
76,000 tons slag yields 76,000 tons of clinker		
Fuel, electricity, handling=\$10/ton	\$760,000	
Total cost for the additional clinker	\$3,040,000	
Imported clinker cost is \$70/ton		
\$70/ton x 76,000 tons	\$5,320,000	
\$30/ton Savings compared to imported clinker	\$2,280,000	

Case #1

Economics: Increased Profit due to Cement Sales from 8.5% Slag Addition

Total Slag Added, tons	76,000	
Increased Clinker Production, tons	76,000	
Increased Cement Production, tons	80,000	(5% gypsum)
Revenue from Increased Cement @ \$90/ton	\$7,200,000	
Clinker Cost	\$3,040,000	
Gypsum Cost @ \$30/ton	\$120,000	
Electricity, Grinding Aid, Handling @ \$8/ton	\$640,000	
Profit	\$3,400,000	

Case #2

- Plant "B" uses slag on a routine basis.
- Plant "B" is a modern precalciner kiln system.
- The annual cement capacity is 900,000 tons.
- The plant needs more clinker due to market demands and had looked at other options:
 - Increase ID fan: environmental permit and need to re-size the main bag house.
 - Install high efficiency cyclones
 - Oxygen enrichment

Case #2

- The plant has experimented with several different EAF slags. Slight changes in plant performance depending upon slag. It is important to keep slag chemistry consistent, i.e. don't mix different slags.
- Clinker production increases range 5-7%.
- The plant adjusts the slag addition rate monthly based on market demand.

Case #3

- Plant "C" a 1.0 million ton plant has used mill scale as an iron source.
- The mill scale has to have a low Oil and Grease content due to VOC issues.
- There was a shortage of mill scale and the plant decided to trial BOF slag.
- The mill scale was also difficult to handle during wet weather.

Case #3

	<u>Mill Scale</u>	<u>BOF Slag</u>
SiO₂	8	22
Al₂O₃	3	7
Fe₂O₃	75	29
CaO	7	33
MgO	2	5
SO₃	0.7	0.7
K₂O	0.9	0.3
Na₂O	0.2	0.1
TiO₂	2	0.6
MnO	0.2	1.3
Cr₂O₃	0.1	0.1
LOI	1	0.5

Case #3

- To hit the iron target, more than twice as much BOF slag was required compared to mill scale.
- Clinker production increased ~ **150 tpd.**
- There was a favorable effect on the plant's VOC's.
- BOF slag handled well during the difficult, wet season.

Case #3

Plant using Mill Scale compared to BOF Steel Slag

	<u>Mill Scale</u>	<u>BOF Slag</u>
Clinker production, tpd	3150	3313
@ 90% runtime, tpy	1,034,775	1,088,320
Increased clinker, tons	-	53,545
Kiln feed, tpd	4860	5035
' tpy	1,596,875	1,653,980
Mill scale, tpy	26,000	
@ \$50/ton, cost/year	\$1,300,000	
BOF Slag, tpy		66,150
@ \$40/ton, cost/year		\$2,646,000
Additional Raw Grinding		
57105 t x 25 kwh/t x \$.06		\$85,650
Additional Handling @ \$1/t		\$57,100
Less other materials		
(40,000 tpy @ \$2)		(\$80,000)
Kiln Feed preparation	\$1,300,000	\$2,708,750
Difference in kiln feed cost		\$1,408,750

Case #3

Plant using Mill Scale compared to BOF Steel Slag

	<u>BOF Slag</u>
Difference in kiln feed cost	(\$1,408,750)
Increased clinker	53,545 tons
Cement equivalent (53,545 tons clinker/0.95)	56,360 tons
Increased Cement Sales (56,360 tons cement * \$90/ton)	\$5,072,400
Gypsum, 2815 tons * \$30/ton	(\$84,450)
Electricity/Grinding Aid/Handling @ \$10/ton	(\$563,600)
Profit	\$3,015,600

Summary

- The technology works
- The type of slag to be used depends on:

The chemistry of the raw materials

1. The availability and economics of the slag
2. The chemistry of the slag

BF slag

MgO Limitations

BOF slag

Fe₂O₃ Limitations

EAF slag

Cr₂O₃ Levels

Fe₂O₃ Limitations

- The amount of slag that can be used ranges from 4% - 12%
- The additional profits can range from USD 2-5 million annually

Overview

- Slag is presently being used in the US to increase clinker production.
- The amount of slag used is based on the chemistry of the slag, how it compliments the chemistry of the other raw materials, and Production/Sales requirements.
- The economics of using slag are based on the cost of the slag vs. the revenue realized from the additional production of clinker.
- Additionally, in Europe the cement companies can benefit from the CO₂ reduction.