Established in 1918 to address the huge volumes of slag being generated by the iron and steel industry. At that time . . . .

- 40,000,000 tons of pig iron being produced.
- 20,000,000 tons of slag being generated.

Association adopted the mission to fully identify new potential applications for this co-product of the iron and steel industry.
National Slag Association
. . . Today!

“SLAG . . . The Material of choice”

- In excess of 20,000,000 tons of slag produced and marketed annually.
- Member companies work closely together to expand utilization and develop new applications.
- Over the past 90 years slag has earned a reputation for long term performance across a wide range of responsible, environmentally sound applications.
- Through a commitment to safe and productive plant operations, NSA member companies continue to demonstrate their dedication to “Safety First”!
SLAG . . . A Green Product in its Own Right!

Sustainability

Environmental

Economic

Social
SLAG . . . An Industrial Co-Product of the Iron & Steel Industry
SLAG

“A material which tends to be mischaracterized and misunderstood!”
Slag usage in road building dates back 2000 years ago to Roman road building.

“Appian Way” in Italy
As early as 1589, Germany made cannon balls out of iron slag.
Perhaps the first introduction of iron slag to America came with the pilgrims as slag was used as ship ballast.
SLAG: A Proud History of Use for this Co-Product!

- Cast iron slag stones were used for masonry work in Europe in the 18th century.
SLAG: A Proud History of Use for this Co-Product!

- Slag roads in England go back to 1813.
First Slag road built in the US in 1830.

By 1880 cast blocks of slag were in general use for street paving in both Europe and America.
SLAG: A Proud History of Use for this Co-Product!

Major early use in America was as ballast for railroads.
WHAT IS SLAG . . . ????
AS OLD AS THE SMELTING PROCESS ITSELF!

Every metallurgical smelting process generates Slag as a co-product.

Slags used in construction applications are primarily co-products of the Iron and Steel making industry.
Types of Slag

- **Iron Blast Furnace Slag (BFS)**
  - Air Cooled
  - Granulated
  - Pelletized

- **Steel Furnace Slag (SFS)**
  - Basic Oxygen Furnace (BOF)
  - Electric Arc Furnace (EAF)

- **Other Slags**
  - Foundry
  - Cupola
  - Ladle Metallurgical Furnace
Steel-Making Process

Integrated Mills:

• **Blast Furnace Slag (BFS)**
• **Basic Oxygen Furnace Steel Slag (BOF)**

Mini Mills:

• **Electric Arc Furnace Steel Slag (EAF)**
Integrated Mills

Blast Furnace Slag (BFS)
Blast Furnace Slag is formed when iron ore or iron pellets, coke and a flux (either limestone or dolomite) are melted together in a blast furnace. When the metallurgical smelting process is complete, the lime in the flux has been chemically combined with the aluminates and silicates of the ore and coke ash to form a non-metallic product called blast furnace slag. During the period of cooling and hardening from its molten state, BF slag can be cooled in several ways to form any of several types of BF slag products.
Iron Slag Making Process Through a Blast Furnace
Iron Blast Furnace
Blast Furnace Slag (BFS)

- Blast Furnace Slag is most often processed by allowing it to slowly cool by ambient air (Air Cool Blast Furnace Slag or ABCF), is processed through a screening and crushing plant, and then processed into different sizes for use primarily as an aggregate.

- In some instances Blast Furnace Slag may undergo either an expansive or pelletizing process for use in different applications.
Granulated Blast Furnace Slag

(GBFS)
Granulated Blast Furnace slag is produced by being rapidly cooled by large quantities of water to produce a sand-like granule with glass-like properties.
Granulated Blast Furnace Slag
Granulated Blast Furnace Slag Applications:

- Ground to produce Slag Cement.
- Construction Aggregate (lightweight fill)
- Raw material in the manufacture of Portland Cement
- Raw material in the manufacture of glass
Steel Slag

- Basic Oxygen Furnace Slag (BOF)
- Electric Arc Furnace Slag (EAF)
Steel Furnace Slag is produced in a (BOF) Basic Oxygen Furnace or an (EAF) Electric Arc Furnace. Hot iron (BOF) and/or scrap metal (EAF) are the primary metals to make steel in each process. Lime is injected to act a fluxing agent. The lime combines with the silicates, aluminum oxides, magnesium oxides, manganese oxides and ferrites to form steel furnace slag, commonly called steel slag. Slag is poured from the furnace in a molten state. After cooling from its molten state, steel slag is processed to remove all free metallics and sized into products.
Steel Slag Made Through A Basic Oxygen Furnace
Basic Oxygen Furnace

Oxygen Furnace

- Fluxes and coolant
- Furnace gasses
- Water jacketed oxygen lance
- Tap hole
- Molten slag
- Molten iron
Mini Mills

Steel Slag

Electric Arc Furnace Slag (EAF)
Process of Steel Slag (EAF)
Steel Slag (EAF)
Electric Arc Furnace
Steel slag is processed as an air-cooled material. The free metallics are magnetically separated and the material is separated and sized into construction aggregates, used as an agricultural soil amendment, as a raw ingredient in Portland cement production, as an environmental remediation material and other uses.
Slags produced by metal casting foundries subject to the type of process being used.

- Cupola Slag (air-cooled or water-quenched)
- Induction Furnace Slag
- Electric Arc Furnace Slag
- Desulphurization Slag

Properties and chemistries vary widely due to the type of processing and materials used.
Ladle Metallurgical Furnace Slag

- Slags that are co-products of specialized iron or steel manufacturing.

- Ferroalloys and Fluxes are added to the ladle to drive attainment of a particular chemistry.

- Slags possessing specialized chemistries such as high CaO can be produced.

- Volumes of Slag produced are generally lower than that typically seen in an iron or steel blast furnace.
Other Proven Uses for Slag!
Clinker From Steel Making Slags

“A Productivity and Environmental Solution”
Why is Slag of interest to the Cement Producer . . . ?
The Chemistry of Slag is very similar to the basic materials found in Portland Cement!
Slag has been proven to be a valuable material addition in the Cement Production Process

- Can be used as a supplemental raw material addition to the materials blended as feed and fed into a kiln to produce cement clinker.
- Can be used as a grinding aid in the cement grinding and finishing process.
CemStar

- **Patented Process that uses Steel Slag and/or ACBF Slag added directly into the back of a cement kiln during the pyro-processing (burning) process to create cement clinker.**
CemStar

- Increases the Production of Cement Clinker. *(Slag is precalcined!)*
- Reduces the consumption of natural fuels while increasing Productivity.
- Reduces Greenhouse Gases
  - CO\(_2\)
  - NO\(_x\)
  - Sox
- Increases the Sustainability of Natural Aggregate Sources.
Steel Furnace Slag

Construction Aggregate Applications
Steel Furnace Slag

Aggregate Properties:
- Rough, cubicle texture
- Increased toughness & soundness
- No deleterious materials

Rounded Uncrushed Gravel

Flat & Elongated Limestone

Cubical Steel Slag
Steel Furnace Slag for Bituminous Paving

Steel Slag has evolved as an ideal aggregate in Hot Mix Asphalt (HMA) surface mixture applications.

- **Superior Skid Resistance**
  - Improved frictional properties
  - Higher coefficient of friction than most natural aggregates.

- **High Shear Strength**
  - Resistance to rutting
Steel Furnace Slag

“Chip and Seal”
Chip and Seal

1. After the surface has been prepared by patching, crack filling, etc. a binder is sprayed from a computer controlled and calibrated spray unit.

2. Then a layer of aggregate is applied using a computer controlled and calibrated self-propelled chip spreader.

3. The process is completed by compacting the surface via several passes from a multi-tired roller.
Physically, many natural aggregates are unable to provide a surface that will resist polishing, therefore, they easily become slippery when wet.

Steel slag contributes a high coefficient of friction to the roads surface by providing the roughness necessary to attain a skid resistant pavement.

Steel Slag, with its hard, angular, skid resistant shape, low absorption, and greater asphalt binder affinity is the most advantageous choice of aggregate for Chip and Seal applications.
"Chip and Seal"

Chip and Seal is a cost-effective method of resurfacing low-volume roadways in rural areas!
Other Construction Applications

- Unimproved Roadways & Parking Lots
- Driveways
- Shoulders & Berms
- Embankments
- Fill Applications
Steel Furnace Slag

Base & Fill Applications

- The chemical composition of some Steel Slag tends to be expansive and should not be used where potential expansion would be detrimental. This is especially true where a dense graded aggregate is used as a base or fill.

- Depending upon the level of potential expansion and material gradation, confined applications such as bases under pavements and structures may need to be avoided.

- Most Steel Slags however are suitable for use in applications where expansion will not be an issue such as in an open-graded fill or road surface course.
Pipe Bedding for Sewer and Storm Water Pipe
Steel Furnace Slag

- Pipe Backfill
- Leach Field Stone
- Septic Stone
Cloacina - Goddess of the Sewers

The Shrine of Cloacina

The model to the right shows the Basilica Aemilia (38 BC) in the Roman Forum with the circular shrine of Venus Cloacina in front. The shrine stood at the place where the Cloaca Maxima entered the Forum (see map below) and may have included a manhole entrance into the sewer. Its placement in the Forum indicates an important status for Cloacina.

Cloacina

Rome was justly proud of its extensive sewer system and embodied this pride in a goddess - Cloacina, the patron goddess of the Cloaca Maxima and the city's sewer system and workers. She is thought to have been initially adopted from Etruscan culture. Over time, Cloacina became identified with Venus, the goddess of love. She was celebrated in a shrine in the Roman Forum (an important civic center in Rome), and was featured on Roman coins and in poems:

O Cloacina, Goddess of this place,
Look on thy supplicants with a smiling face.
Soft, yet cohesive let their offerings flow,
Not rashly swift nor insensitively slow.

Cloaca Maxima - Rome's Grand Sewer

The largest sewer in Rome's system was a massive drain made of cut stone, known as the Cloaca Maxima, or "Main drain," portions of which still exist and are in service today. Construction of the Cloaca Maxima began circa 500 BCE, probably by Etruscan workers. Its original purpose was to drain a marsh upon which a large portion of the city was eventually built. The Cloaca Maxima discharged its flow into the Tiber River. The Cloaca Maxima soon became a "commodity system," since most waste from the city was thrown into the streets, waiting for either the city's extensive street-flushing program or rain to flush it into the underground sewer system. Early on, drains from public buildings and the homes of important public officials were the only "private" connections allowed to drain directly into the system and the Cloaca Maxima. Later, from other buildings and the vast majority of the city's homes were illegal until around 150 AD.

ROUTE OF THE CLOACA MAXIMA

- Basilica Aemilia
- House of Venus Cloacina
- Route of the Cloaca Maxima
- Cloaca Maxima enters the Forum
- Cloaca Maxima discharges into the Tiber River


*Figures: 6. Cloacina, Goddess of this place.


*Figures: 6. Cloacina, Goddess of this place.


Sponsored by the Pima County Waterway Management Department and the Arizona Water & Pollution Control Association.
## COMMON USES FOR SLAG

<table>
<thead>
<tr>
<th>Blast Furnace Slag</th>
<th>Steel Slag</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Air-Cooled</strong></td>
<td><strong>Pelletized</strong></td>
</tr>
<tr>
<td>Asphalt Aggregate</td>
<td>Concrete Masonry Aggregate</td>
</tr>
<tr>
<td>Concrete/Masonry Aggregate</td>
<td>Lightweight Concrete</td>
</tr>
<tr>
<td>Insulation/Mineral Wool</td>
<td>Insulation</td>
</tr>
<tr>
<td>Cement Mfg. Raw Feed</td>
<td>Lightweight Fill</td>
</tr>
<tr>
<td>Agriculture/Soil Amendment</td>
<td>Road Base</td>
</tr>
<tr>
<td>Base &amp; Fill Material</td>
<td></td>
</tr>
<tr>
<td>Roof Aggregate</td>
<td></td>
</tr>
<tr>
<td>Railroad Ballast</td>
<td></td>
</tr>
<tr>
<td>Glass Manufacture</td>
<td></td>
</tr>
<tr>
<td>Environmental Applications</td>
<td></td>
</tr>
<tr>
<td>Gabions/Rip Rap</td>
<td></td>
</tr>
</tbody>
</table>
Agricultural Applications

- Substitute for Agricultural Lime
- Valuable for Remineralization: Calcium, Iron, Copper, Boron, Magnesium, Zinc, Manganese, Sulfur, Molybdenum
Slag’s use for Environmental Remediation

Water Purification

Permeable Reactive Barrier

Phosphorus Removal

Water Filtration

Erosion Control
Environmental Remediation

- Water Purification
- Hazardous Chemicals
- Permeable Reactive Barriers

- Acid Remediation
  - Acid Mine Drainage
  - Phosphorus

- Waste Pollution Remediation (Constructed Wetlands Technology)
  - Manure Pit Effluents
  - Barnyard & Feed Lot Effluents
  - Milk House Effluents
Slag Utilization for Water Pollution Remediation
Slag for Permeable Reactive Barriers
Slag for Permeable Reactive Barriers
SLAG for Acid Mine Drainage
Presentation on the utilization of Slag to reduce Acid Mine Drainage

Jim Gue – Ohio Department of Natural Resources
“PASSIVE TREATMENT OF ACID MINE DRAINAGE USING STEEL SLAG IN THE HUFF RUN WATERSHED”
Huff Run Watershed

- Muskingum Conservancy District
- Tuscarawas River Basin
- Conotton Creek
- 10 miles length
- 14.1 sq miles
A Primary Huff Run AMDAT Goal:

“Identify and develop AMD abatement Projects in reaches 4 and 5 to buffer downstream episodic low flow pH excursions.”
## Pre-Construction Water Quality

<table>
<thead>
<tr>
<th>Project Sample Location</th>
<th>pH</th>
<th>Fe</th>
<th>Mn</th>
<th>Al</th>
</tr>
</thead>
<tbody>
<tr>
<td>Seep at Headwaters</td>
<td>5.8</td>
<td>.648</td>
<td>18.5</td>
<td>.357</td>
</tr>
<tr>
<td>Pond 1</td>
<td>2.99</td>
<td>6.94</td>
<td>44.1</td>
<td>21.3</td>
</tr>
<tr>
<td>Pond 2</td>
<td>6.64</td>
<td>.258</td>
<td>1.44</td>
<td>&lt;.25</td>
</tr>
<tr>
<td>Impoundment 4</td>
<td>4.64</td>
<td>.169</td>
<td>12.3</td>
<td>.987</td>
</tr>
<tr>
<td>Impoundment 6</td>
<td>6.28</td>
<td>1.85</td>
<td>5.47</td>
<td>&lt;.25</td>
</tr>
<tr>
<td>Wetland Outlet</td>
<td>4.78</td>
<td>.302</td>
<td>15.1</td>
<td>.51</td>
</tr>
<tr>
<td>Site Discharge</td>
<td>3.97</td>
<td>.75</td>
<td>18.8</td>
<td>3.33</td>
</tr>
</tbody>
</table>

pH (SU)

Metals (mg/l)
Steel Slag Advantages:

- Steel slags yield several hundred times more alkalinity per equal weight than limestone
- High alkalinity with low contact time
- Low cost ($12.00/ton at Lindentree Project)
- Ease of availability
- Long-term passive treatment
Limestone/Steel Slag Channel
Limestone/Slag Treatment Swale
Limestone Rip-Rap Channel
# Discharge Analysis (pH)

<table>
<thead>
<tr>
<th>Site Location</th>
<th>Pre-construction (4-11-02)</th>
<th>Post-construction (11-17-04)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pond 6 discharge (limestone channel 2)</td>
<td>6.28</td>
<td>6.0</td>
</tr>
<tr>
<td>Slag channel 5</td>
<td>6.25, 4.87, 4.64, 6.8</td>
<td>10.5</td>
</tr>
<tr>
<td>Pond 1 (slag channel 7)</td>
<td>2.99</td>
<td>11.0</td>
</tr>
<tr>
<td>Channel 6</td>
<td>4.5, 6.64</td>
<td>10.0</td>
</tr>
<tr>
<td>Bog discharge into slag swale</td>
<td>5.88</td>
<td>7.0</td>
</tr>
<tr>
<td>Slag Swale Outlet</td>
<td>...</td>
<td>11.0</td>
</tr>
<tr>
<td>Weir outlet</td>
<td>4.78</td>
<td>10.0</td>
</tr>
<tr>
<td>Project Outlet Channel, downgrade</td>
<td>3.97</td>
<td>9.0</td>
</tr>
<tr>
<td>Brass Road Culvert</td>
<td>3.97</td>
<td>8.0</td>
</tr>
</tbody>
</table>
Acidity/Alkalinity

(mg CaCO3/L)
SLAG for Constructed Wetlands
Use of Steel Slag in Constructed Wetlands Technology to effect P (Phosphorus) removal.
Constructed Wetlands
Constructed Wetlands
Constructed Wetlands
UKRAINE (Before)
Constructed Wetlands
UKRAINE (After)
Constructed Wetlands
Africa
Constructed Wetlands
Nevada
Use of Steel Slag as a filter medium to treat water runoff from barnyards, feedlots, and milk house effluent.
Steel Slag Potential Use
Steel Slag Potential Use
Steel Slag Potential Use

Figure 4 - Factors affecting the input, fate, and transport of P in agricultural systems. Numbers in parentheses are based on approximate farm inputs of P in animal feed and fertilizer and output in animal produce (A) and manure and fate in soils, crops, and transport in runoff (B). Adapted from Howarth et al. (2000) and Sims and Sharpley (2005).
Steel Slag Potential Use
SLAG as a “Green” Material!

- Hundreds of years of use as an industrial co-product!

- A multitude of applications which contribute to its capabilities as a “Green Material”!
“The recovery and reuse of slag conserves tens of millions of tons per year of other natural resources”

American Iron and Steel Institute
SLAG & the LEED Program!

“SLAG is a recognized industrial co-product under the LEED Program!”
LEED stands for **Leadership in Energy and Environmental Design**.

It is a green building rating system first launched by the US Green Building Council (USGBC) in 1998. The USGBC is a not for profit organization made up of companies and organizations from every sector of the building industry, who work to promote buildings that are environmentally responsible, healthy and profitable.
LEED is a third party certification program and the nationally accepted benchmark for the design, construction and operation of high performance green buildings.

LEED gives building owners and operators the tools they need to have an immediate and measurable impact on their buildings’ performance.

Establishes a rating system to evaluate green construction materials and building systems.
Encourages and accelerates global adoption of sustainable green building and development practices through the creation and implementation of universally understood and accepted tools and performance criteria.

Developed by USGBC, LEED is a practical rating tool for green building design and construction that provides immediate and measurable results for building owners and occupants.
LEED: Green Building Rating System

LEED promotes a whole-building approach to sustainability by recognizing state-of-the-art strategies for performance in five key areas of human and environmental health:

- Sustainable site development
- Water savings
- Energy efficiency
- Materials selection
- Indoor environmental quality

Builders can obtain credits for using materials or systems which are more energy efficient in construction, utilize recycled waste materials from other industries, or result in a more energy efficient and environmentally sound building.
SLAG

“A Green Product in its own right ! ! ! “
SLAG . . . .
A Hot Product with a myriad of uses and applications! ! ! ! !
SLAG . . . An Industrial Co-Product of the Iron & Steel Industry

Questions ? ? ? ?
CONTACT INFORMATION

➢ John Murphy
   • The Edw. C. Levy Company
   • Office #: (256) 306-9477
   • Fax #: (256) 306-9488
   • Cell #: (574) 876-0466
   • Email: jmurphy@levyco.net

➢ National Slag Association
   • Website: www.nationalslag.org
SLAG . . . An Industrial Co-Product of the Iron & Steel Industry

THANK YOU ! ! ! ! !