

Ferrous Slag: Glossary

A

AGGREGATES

Granular material used in the construction industry. Aggregates can be natural, manufactured or recycled.

AIR COOLING

Process where the slag is allowed to cool slowly by leaving it in contact with ambient temperature air.

AIR-COOLED BLAST FURNACE SLAG (ABS)

When blast furnace slag cools slowly in slag beds, crystalline air-cooled blast furnace slag is produced. As well as being used as a building material, air-cooled blast furnace slag can also be processed into metallurgical lime, a fertiliser.

AOD PROCESS

AOD stands for 'argon oxygen decarburisation', a refining process associated with the production of stainless steel. Most stainless steel is initially produced in an electric arc furnace before being transferred to a separate furnace for refining to achieve the precise metallurgical content required – a process known as secondary metallurgy. In the AOD process, a mixture of argon and oxygen is blown through the molten steel in the AOD converter, and the oxygen achieves the main objective of oxidising unwanted carbon in the steel melt. But because the vital and expensive chromium contained in all stainless steels is also prone to oxidation and subsequent loss with the process slag, the argon is introduced to inhibit this reaction.

ASHES

Ash is the solid residue produced by combustion processes. Industrial combustion processes are generally aimed at generating energy from coal, oil or household waste.

The primary objective is therefore not the deliberate production and use of ash, as is the case in metallurgical processes, where the focus is on producing pure molten metal.

ASPHALT

A mixture of aggregate, bitumen and, where applicable, other additives. The binding agent, bitumen, is thermoviscous: it is liquid at 200 °C and becomes stiff/solid at operating temperatures. For laying, asphalt is produced hot in special mixing plants, delivered to the construction site, laid whilst still hot and compacted as it cools. The production of asphalt is a high-value application for ferrous slag.

B

BASIC OXYGEN FURNACE/BASIC OXYGEN FURNACE SLAG (BOF)

A basic oxygen furnace – also known as an LD converter – is a steel-making furnace, in which hot metal from the blast furnace, with certain amounts of steel scrap, is converted into steel. High-purity oxygen is blown through the molten bath to lower the carbon content. Fluxes are used to reduce other unwanted elements. These fluxes combine with silicates and oxides to form liquid slag that floats on the surface of the liquid metal.

Basic oxygen furnace slags are steel furnace slag and are classified as ferrous slag. It is produced during the manufacture of crude steel using the Linz-Donawitz process (blast furnace process, converter process). It is formed as molten rock during the processing of hot metal and processed steel scrap into crude steel in the converter process.

BLAST FURNACE

A blast furnace is a continuously operated shaft furnace. In the blast furnace, the iron oxides contained in ores, sinter or pellets are reduced and melted into liquid hot metal. This process produces a dust-laden blast furnace gas and, as a by-product, blast furnace slag.

BLAST FURNACE CEMENT

The main components of blast furnace cement are Portland cement clinker and

granulated blast furnace slag. It is defined in the European cement standard EN 197-1. Accordingly, it contains 36–65% by mass (CEM III/A), 66–80% by mass (CEM III/B) or 81–95% by mass (CEM III/C) of granulated blast furnace slag.

BLAST FURNACE LIME

Product from blast furnace slag obtained by milling the slag. As essential ingredients it contains calcium and magnesium silicates as well as oxides and is used as fertiliser.

BLAST FURNACE SLAG

Blast furnace slag is produced as molten rock during the production of hot metal from ores and mineral additives in a blast furnace. Blast furnace slag is a collective term for air-cooled blast furnace slag and granulated blast furnace slag.

BOUND ROAD PAVING

Road pavements made from aggregates and binders that achieve a high degree of stiffness. Ferrous slag is used in various mix designs to produce durable pavements.

BY-PRODUCT

A by-product is a substance produced during a manufacturing process whose primary purpose is not the production of that substance, but which has a significant impact on the properties of the main product. Under European legislation on the circular economy, by-products must meet four conditions:

- the further use of the substance is guaranteed;
- the substance can be used directly, without further processing beyond normal industrial practice;
- the substance is produced as an integral part of a production process; and
- its further use is lawful, i.e. the substance meets all relevant product, environmental and health protection requirements for the specific use and does not overall lead to adverse effects on the environment or human health.

These conditions are definitely met by ferrous slag, which is used as a secondary raw material, for example in cement production, as aggregate or in aggregate mixtures for road construction, and as a fertiliser.

C

CBR VALUE

California Bearing Ratio (CBR) value is defined as the ratio of load required to cause a specified penetration of a standard plunger into the test sample to the load required to produce the same penetration of the same plunger into a standard aggregate sample. It is expressed as a percentage and is broadly used in design of the base and the sub-base material for pavement.

CEMENTITIOUS PROPERTY

A property of a material to gain strength when mixed with water. The chemical reaction is called hydration.

CEMENT

Cement is a hydraulic binder, meaning that, upon contact with water, it forms durable, strength-developing reaction products, whether above or below the waterline. Cement is used in the manufacture of concrete, mortar and other construction products. There are many different types of cement, which vary in their composition, fineness and technical applicability. EN 197-1 for 'ordinary cement' alone currently covers 27 different types of cement and 9 different strength classes.

CIRCULAR ECONOMY

The use of slag-based building materials and fertilisers from the steel industry has long made a significant contribution to the goals of the circular economy. The circular economy is a model of production and consumption in which existing materials and products are shared, reused, repaired, refurbished and recycled for as long as possible.

In this way, the life cycle of products is extended and the consumption of primary resources is sustainably reduced.

CONCRETE

Concrete is a mixture of cement, aggregate, water and, where applicable, concrete admixtures (e.g. granulated blast furnace slag, coal fly ash) and chemical concrete additives. Initially soft and malleable, concrete hardens after setting above or below water and can achieve high strengths. Due to its versatile technical properties, its relatively low cost and the almost universal availability of aggregates and water, concrete is the most widely used building material. In Europe, the requirements for concrete are defined in EN 206.

CONVERTER LIME

Product obtained by milling basic oxygen furnace slag (BOS) as well as sieving disintegrated basic oxygen furnace slag (BOS) or ladle slag (SMS) from the treatment of non-alloyed steels. It contains the essential ingredients calcium and magnesium silicates as well as oxides, and is used as fertiliser.

CRUDE STEEL

The term means the first solid steel product upon solidification of liquid steel. Also known as raw steel.

CUBIC GRAIN

A rock grain that is approximately round or cuboid in shape (length-to-thickness ratio ≤ 3)

D

DECARBONISATION

As part of the decarbonisation of the steel industry, the blast furnace is being replaced by a direct reduction plant. Instead of coal or coke, natural gas or hydrogen is used to

reduce the iron ore. This enables CO₂ emissions from steel production to be significantly reduced.

DECARBURISATION

Decarburisation refers to the removal of carbon from iron or steel, usually by blowing in oxygen to form carbon dioxide. This results in a low-carbon composition of the steel and thus in ductile behaviour, enabling the steel to be formed in subsequent process steps.

DESULPHURISATION SLAG

Produced during the desulphurisation of hot metal to remove sulphur before it is processed into crude steel.

DOLOMITE

A natural sedimentary rock consisting principally of the mineral dolomite [CaMg(CO₃)₂]. It is used in the manufacture of cement, as a building stone and as a fluxing agent in the iron and steel making operations.

E

ELECTRIC ARC FURNACE (EAF)

An electrical furnace in which the thermal effect of an electric arc is used to melt materials like steel scrap or iron. Once the furnace is charged and covered, graphite electrodes are lowered through holes in the roof. The electric arc travelling between the electrodes and the metallic charge creates intense heat which melts the charge.

Alloying elements can be added during the process.

ELECTRIC ARC FURNACE SLAG (EAF C/EAF S)

Electric arc furnace slags are steel furnace slags and are classified as ferrous slags. They are produced as molten rock during the processing of prepared steel scrap, hot metal and direct reduced iron (DRI) into crude steel in the electric arc furnace process.

Under REACH, electric arc furnace slag is classified as EAF C from the carbon steel process and EAF S from the production of high-alloy steels.

F

FERROUS SLAG

Molten rock from metallurgical processes in both iron and steel production. Ferrous slag includes both blast furnace slag and steel furnace slag.

G

GLASS FORMATION

Conversion into a glass-like substance by rapidly cooling liquid slag. The aim is to minimise the crystalline content. Slag used for cementitious purposes must consist solely of vitrified (glass-like) material, as otherwise it will lack latent hydraulic properties.

GRANULATION

The vitrification of molten slag by treating normally with large volumes of high-pressure water. The water both instantaneously cools and breaks up the slag into granules up to 5 mm in size. There are also dry granulation technologies, such as air granulation or rotary disc granulation.

GRANULATED BLAST FURNACE SLAG (GBS)

Conversion into a glass-like substance by rapidly cooling liquid slag. The aim is to minimise the crystalline content. Slag used for cementitious purposes must consist solely of vitrified (glass-like) material, as otherwise it will lack latent hydraulic properties. If the liquid blast furnace slag is converted into granules < 5 mm by means of shock cooling in what are called granulation plants, the result is granulated blast furnace slag. Due to its chemical composition and its largely vitreous grain structure, it possesses latent hydraulic properties.

GROUND GRANULATED BLAST FURNACE SLAG (GGBS)

Ground granulated blast furnace slag is granulated blast furnace slag ground to cement fineness. It is either a component of cement (blast furnace cement, Portland slag cement) or is used directly as a concrete admixture. The material requirements for ground granulated blast furnace slag as a concrete admixture are defined in EN 15167-1.

H

HOT METAL

Hot, liquid, metallic iron product obtained upon reduction of iron ore in a blast furnace. It proceeds to the basic oxygen furnace in molten form or is cast as pig iron.

HYDRAULIC PROPERTY

The term 'hydraulic property' refers to the ability of a non-metallic, finely ground substance to react spontaneously with water to form solid, dimensionally stable reaction products, known as hydrate phases. This reaction, known as hydration, can take place both in air and under water. Examples of hydraulic materials include cements and hydraulic limes.

I

IRON ORE

An ore from which iron can be extracted. It is the primary raw material in the manufacture of steel. Iron ore occurs in most countries in varying forms of purity. Most iron produced in Europe is made from high-purity ores from Australia, South Africa and Brazil which can contain over 70% iron.

L

LADLE

A vessel for receiving and handling liquid steel. It is constructed of a refractory-lined steel shell.

LADLE FURNACE

A ladle furnace is a piece of equipment used in secondary metallurgy in which steel is finely alloyed and the temperature is controlled using graphite electrodes for casting.

LD PROCESS

LD is the abbreviation for the Austrian towns of Linz and Donawitz, where the LD process was developed; the converter used in this process is a crude steel production furnace in which hot metal from the blast furnace – mixed with around 20% steel scrap – is processed into crude steel. High-purity oxygen is blown through the molten bath to reduce the carbon content (decarburisation, ‘blowing’). Slag formers are used to reduce other undesirable elements. These substances combine to form silicates and ferrites, creating a liquid slag that floats on the surface of the crude steel.

LIME

Calcium oxide (CaO), a product derived from burnt (calcined) limestone. It is used as a fluxing agent in iron- and steel-making operations. The flux, which may also include additions of dolomite or limestone, combines with other non-metallic components and results in liquid slag.

LIMESTONE

A natural sedimentary rock consisting primarily of calcium carbonate (CaCO₃). It is used as building stone, in the manufacture of lime, carbon dioxide, cement or as a fluxing agent in iron- and steel-making operations.

M

MIDREX®

The MIDREX® Process is a direct reduction process where the removal of oxygen from iron ore occurs without melting. For more information, visit www.midrex.com

N

NON-FERROUS SLAG

A general term for slag produced as molten rock during the manufacture of lead, ferrochrome, copper, nickel, zinc and waelz oxide. The obtained metallurgical slag can solidify in a glassy or crystalline form.

P

PELLETISATION

Molten slag is thrown through the air by a spinning drum and water is sprayed into the area from the sides and ceiling of the structure. Both air and water cool the slag. The smaller particles produced are glassy and are suitable for cementitious use. The larger lumps (greater than 10 mm) tend to be crystalline and thus used for aggregate.

PIG IRON

Hot metal, which was cast into ingots (known as pigs) so that it can be used in solid form.

POLISHED STONE VALUE (PSV)

The PSV provides an indication of a stone's resistance to polishing caused by traffic, as determined by a standard laboratory test. High values indicate good slip resistance. Aggregates from steel furnace slag typically provide high polished stone values.

PORTLAND CEMENT

A hydraulic cement made by heating a limestone and clay mixture in a kiln and pulverising the resulting material.

PORTLAND BLAST FURNACE CEMENT

The main components of Portland blast furnace cement are Portland cement clinker and granulated blast furnace slag. It is defined in the European cement standard EN 197-1. According to this standard, it contains 6–20% by mass (CEM II/A-S) or 21–35% by mass (CEM II/B-S) of granulated blast furnace slag.

R

REACH (REGISTRATION, EVALUATION, AUTHORISATION AND RESTRICTION OF CHEMICALS)

Regulation of the European Union of 18 December 2006. REACH deals with the manufacture and use of chemical substances and their potential effects on human health and the environment.

RESOURCE CONSERVATION

The careful use of natural and non-renewable primary raw materials, with the aim of protecting the environment. The reckless consumption of natural raw materials, such as natural rocks, can lead to resource scarcity. Steelworks slag acts as a substitute for natural rock and is therefore considered the best example of resource conservation in practice. Since 1949, its use has prevented the extraction of more than 1.2 billion tonnes of primary raw materials in the EU and the UK.

RESOURCE EFFICIENCY

As our consumption of natural resources far exceeds the Earth's capacity to regenerate, the optimal use of existing raw materials to conserve natural resources is a key competence for sustainable societies.

S

SECONDARY METALLURGICAL SLAGS (SMS)

In order to meet today's quality requirements for steel, it is necessary to carry out certain process steps – which were previously performed in the melting vessel (converter, electric furnace) or in the ladle – in separate secondary metallurgical processes. Using lime and other slag-forming agents, slags consisting mainly of lime, silica and alumina are formed. SMS refers to those slags from iron and steel production that are formed during the post-treatment of liquid crude steel.

SILICATE LIME FERTILIZER

Lime fertiliser derived from slag produced by metallurgical processes such as blast furnaces, converters or ladles, in which the lime content is predominantly present in a silicate-bound form.

SKID RESISTANCE

The frictional resistance that the road surface offers to vehicle tyres when braking out of bends. It is usually measured on a wet road surface. Roads with ferrous slag typically have very good frictional resistance values. (see PSV)

SKIMMER

A slag skimmer is special equipment for separating hot metal from liquid slag. Once the taphole in the blast furnace is drilled open, hot metal and slag flow down a deep trench called a 'trough'. The hot metal flows through a skimmer opening, down the 'iron runners'. Since the slag is less dense than iron, it floats on top of the iron, down the trough, hits the skimmer and is diverted into the 'slag runners'. The liquid slag flows into granulation plants or 'slag pots'.

SLAG

By-product of ferrous and non-ferrous metal manufacture which is composed of those elements not required in the molten metal. Slag is a metallurgical by-product that is essential for the production of metals.

SLAG METALLURGY

Slag metallurgy deals with all aspects of the production, treatment, solidification, processing and recycling of ferrous slag. This encompasses processes involving both the molten and solid states. The aim of these processes is generally to improve the physical or environmental properties of the slag, or its heat content.

STAINLESS STEEL SLAG (EAF S)

Slag produced during the manufacture of high-alloy steel ('stainless steel') (see also electric arc furnace slag, AOD process, VD process, VOD process)

STEEL FURNACE SLAG (SFS)

Molten rock produced during steel manufacturing. It is named according to the specific steelmaking process (e.g. basic oxygen furnace slag, electric arc furnace slag from carbon steel production, stainless steel production and secondary metallurgical slags from the post-treatment of crude steel).

T

THOMAS PHOSPHATE

Basic slag (Thomas slag) from the 'Thomas process', a process for the dephosphorisation of hot metal, with a phosphate (P_2O_5) content of 10–15%. For many decades, Thomas phosphate was the most commonly used phosphate fertiliser in European agriculture. Nowadays, the Thomas process has been replaced by other smelting processes using low-phosphate iron ores. Consequently, Thomas phosphate is no longer produced.

TRANSFORMATION

In the context of steel production, 'transformation' refers to the decarbonisation of the steel industry, which involves a massive overhaul and the construction of new integrated steelworks. A key part of this is the replacement of the blast furnace – which, due to the nature of the process, emits large quantities of CO₂ – with a direct reduction plant. This

slag-free process produces DRI , which is melted down in downstream units. In these units, the gangue still present is converted into slag, resulting in new by-products whose potential applications are currently being researched. This may require additional conditioning of these slags.

U

UVCB SUBSTANCE

For identification and naming in REACH, substances are divided into two main groups:

1. “Well-defined substances”: substances with a defined qualitative and quantitative composition.
2. “UVCB substances”: substances of Unknown or Variable composition, Complex reaction products or Biological materials.

Variability of composition for well-defined substances is specified by the upper and lower limits of the concentration range(s) of the main constituent(s). For UVCB substances, the number of constituents is relatively large and/or the composition is, to a significant degree, unknown and/or the variability of composition is relatively large or poorly predictable. As a consequence, other types of information for identification is necessary. Those identifiers can be “process related” or “source related”. For historical reasons, slags have been registered as UVCB substances.

V

VD PROCESS

Vacuum degassing process, a secondary steel-making operation in which the molten steel is exposed to a vacuum. The aim is to improve steel quality by removing gases, improving steel cleanliness and obtaining a greater uniformity of the chemical composition.

VITRIFICATION

Making into glassy substance by rapidly cooling molten slag. The aim is to minimise crystalline content. Slag for cementitious purposes can only be composed of vitrified (glassy) material.

VOD PROCESS

Vacuum oxygen decarburisation. A refinement of stainless steel that reduces carbon content. Molten, unrefined stainless steel is heated and stirred by an electrical current while oxygen enters from the top. Many undesirable gases escape from the stainless steel and are evacuated by a vacuum pump. Alloys and other additives are then mixed in to refine the molten stainless steel further.

VOLUME STABILITY

A material is said to be dimensionally stable if its volume (e.g. that of a piece of rock) does not change as a result of environmental factors (particularly moisture).

W

WEATHERING

Subjecting stockpiles of slag to normal weather as well as, where necessary, to additional artificial irrigation, with the principal objective of getting water to react with calcium oxide inclusions, in order to ensure the required volume stability.