The role of slags and other by-products within circular economy in the steel industry

5.–6. MARCH 2025

ESTEP Focus Group Circular Economy & FEhS-Institute

- Current status of slag recycling and activities related to environmental regulation in South Korea
- Rick Lim (POSCO-Europe)

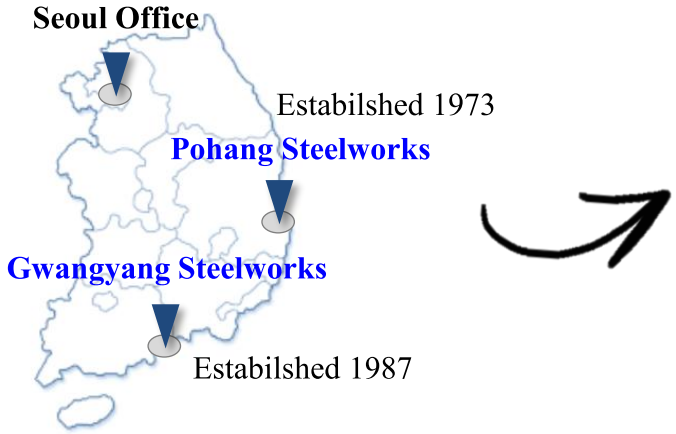
ESTEP
European Steel Technology Platform

INSTITUT FÜR BAUSTOFF FORSCHUNG
FEhS

posco

POSCO Overview

Business Place in KOREA



	Pohang	Gwangyang
Crude Steel Production	14.5 million ton	21.1 million ton
Number of Employee	7,409	6,250
Featured Products	Hot rolled steel, Wire rod, STS steel etc	High strength steel for automotive, Hot rolled steel, Thick plate etc

Company Profile

○ The world's most competitive steel company for 15 consecutive years by World Steel Dynamics

※ Ranking('24.12) : POSCO (Korea) – Nucor (USA) – Nippon Steel (Japan) – ArcelorMittal (Multinational) – BaoWu Steel (China)

○ Manages 13 production subsidiaries and 26 processing centers spread across 13 countries abroad

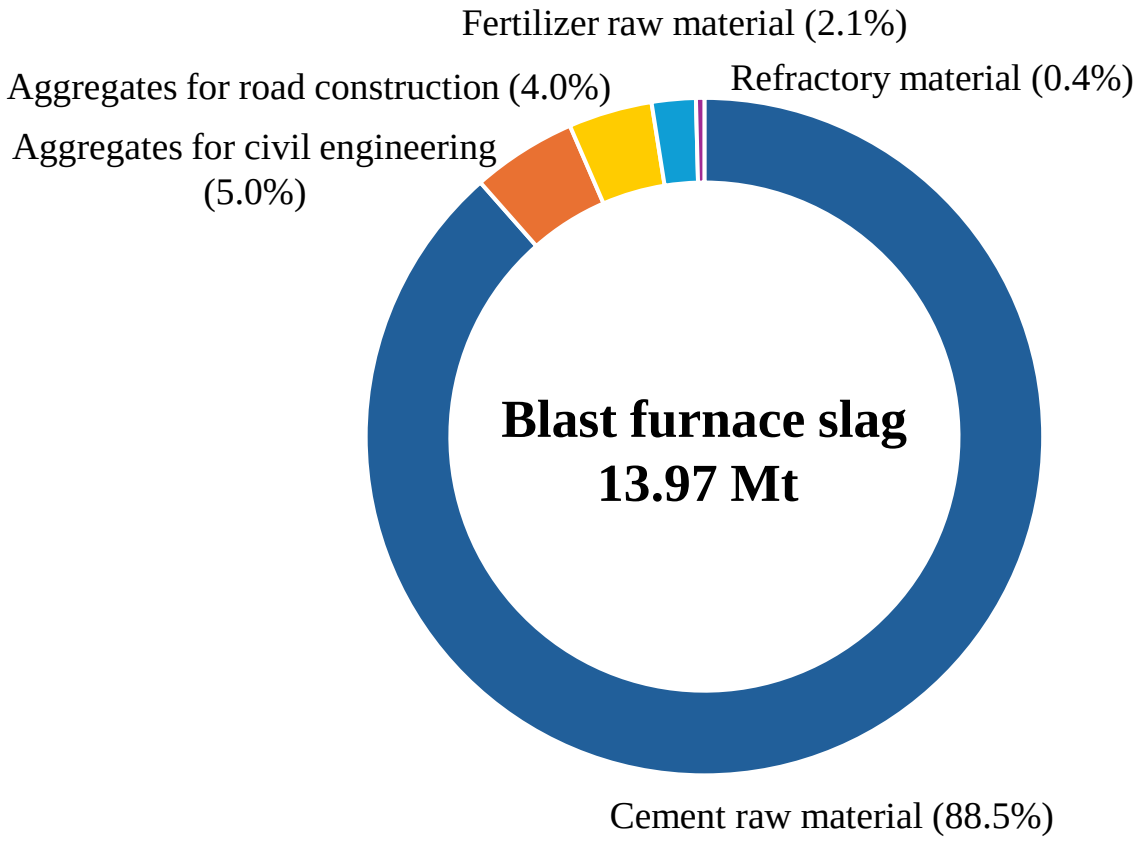
○ Total asset is 31 billion euros and revenue is 25 billion euros in FY 2022

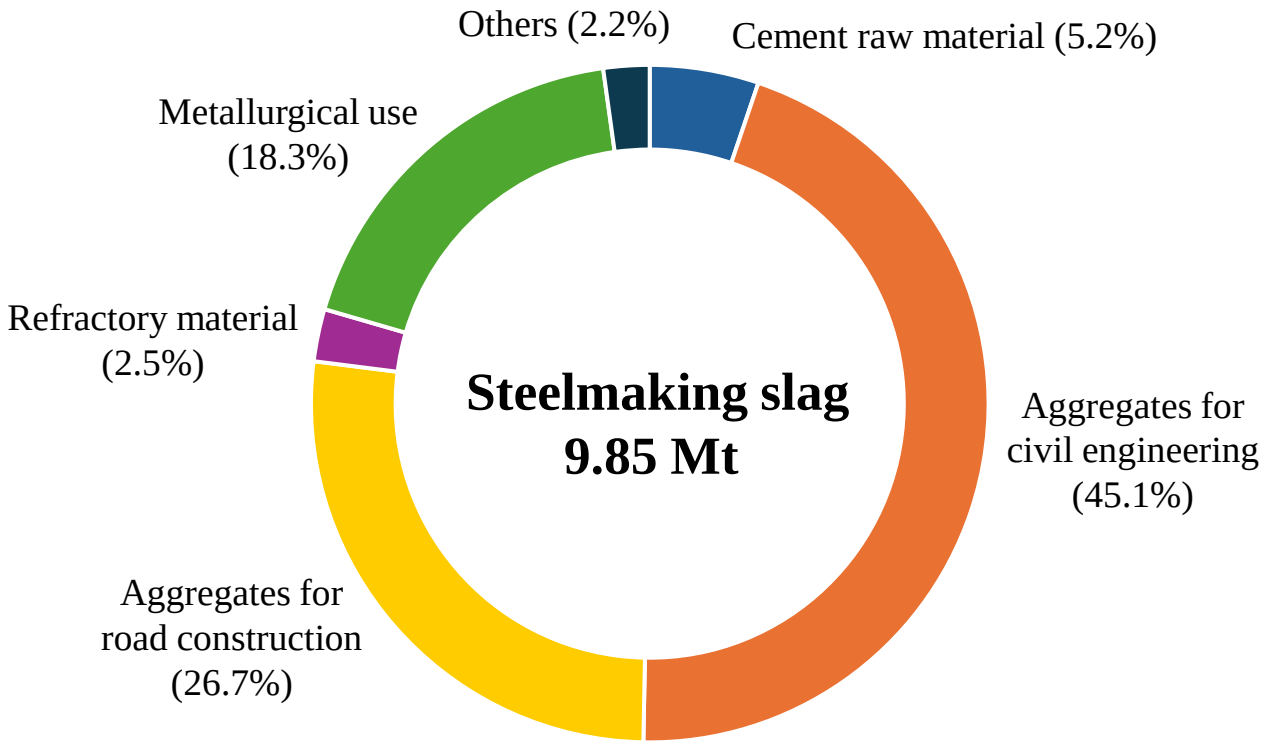
○ Set an objective to become carbon neutral by 2050. Put together the '2050 Carbon Neutrality Roadmap'

※ (Short-term) deploying electric arc furnace, utilizing low-carbon raw materials, low HMR operation, (Long-term) HyREX

Slag production and utilization

In 2023, 24 million tons of steel slag was generated in Korea. Most of the slag was utilized in various applications.



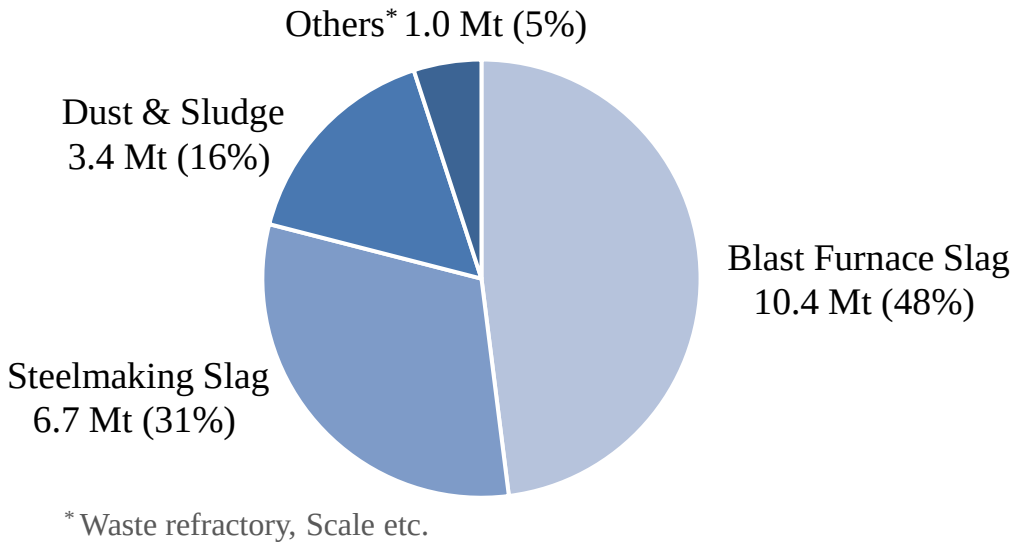


※ Source : Korea Iron & Steel Association

By-product overview of POSCO

In 2023, 21.5 million tons of by-product was generated in POSCO and the by-product recycling rate was 98.8%

POSCO	
Generation of By-products (Mt)	**21.5**
Pohang Works	9.0
Gwangyang Works	12.5
Crude Steel Production (Mt)	**35.6**
Pohang Works	14.5
Gwangyang Works	21.1
Specific Amounts (kg/t-s)	**604**
Recycling Rate (%)	**98.8**
Pohang Works	98.5
Gwangyang Works	99.1



* Waste refractory, Scale etc.

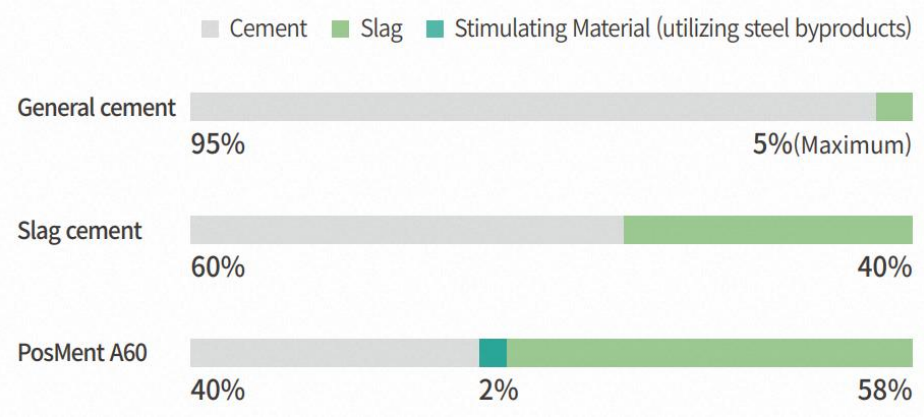
By-Product	Recycling Rate (%)
Blast Furnace Slag	100 %
Steelmaking Slag	100 %
Dust & Sludge	94 %
Others	98 %

Slag cement

Advanced slag cement technology was developed to increase slag utilization and further reduce CO_2 emission

○ Slag cement can lower CO_2 emission by replacing cement clinker but has disadvantage of low early-age compressive strength in concrete

○ Alkali-activator manufactured by steelmaking slag adopted to compensate for the decrease in the early-age compressive strength

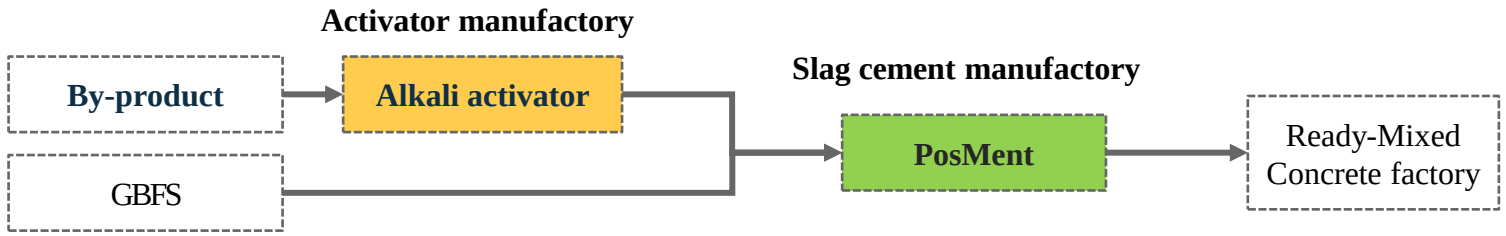


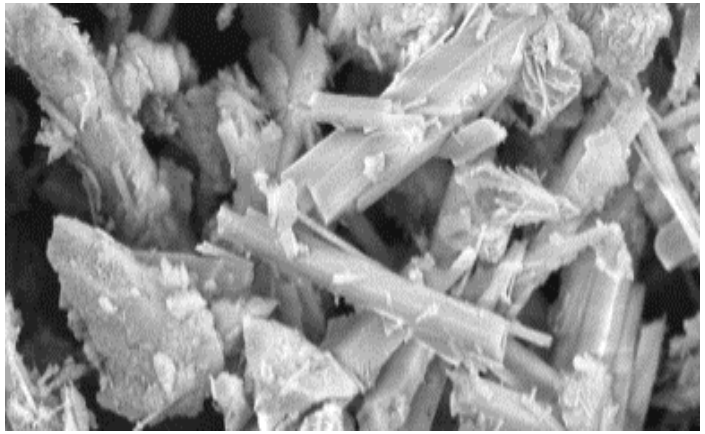
Alkali-activator enhances the creation of ettringite hydrate during hydration of the slag cement

○ Formation of the ettringite increases early-age strength of concrete and decrease drying shrinkage of the concrete structure

$$3CaO{\cdot}Al_2O_3 + 3CaSO_4{\cdot}2H_2O + 26H_2O \rightarrow 3CaO{\cdot}Al_2O_3{\cdot}3CaSO_4{\cdot}32H_2O$$

○ The patent was transferred to an additive manufacturing company





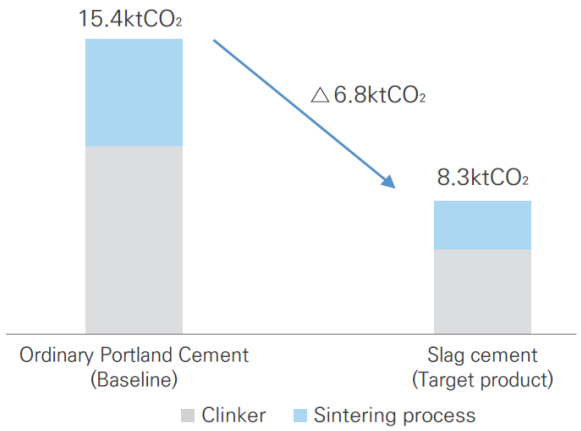
Avoided GHG emissions (Slag cement)

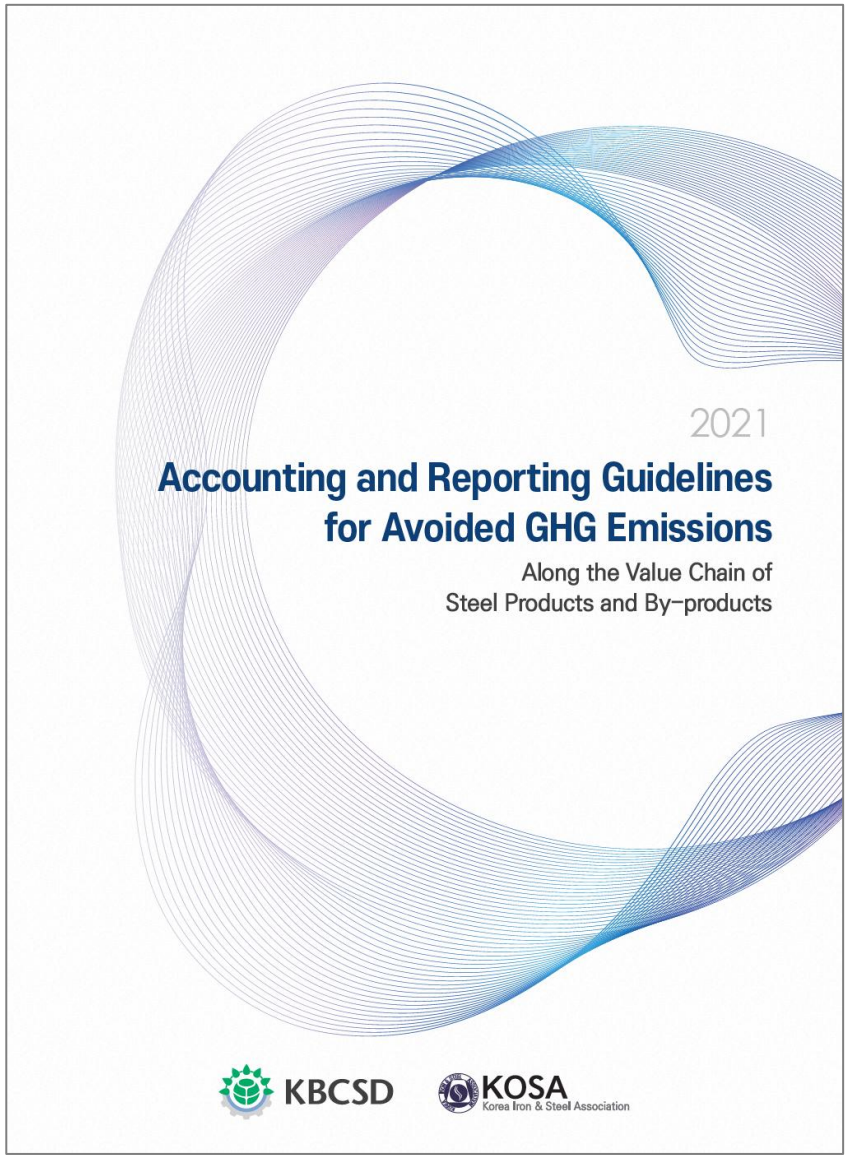
- **Steel industry has contributed to GHG emission reductions across society with its products. This guideline was developed to facilitate avoided emissions by collaborating with value chain partners**
- **It was developed with reference to relevant guidelines and standards**
  - The essential role of chemicals. Guidelines: Accounting for and reporting greenhouse gas emissions avoided along the value chain based on comparative studies. (WBCSD/ICCA, 2013)
  - Guideline for quantifying GHG emission reductions of goods or services through global value chain (METI, 2018)
  - Estimating and reporting the comparative emissions impacts of products (WRI, 2019)
- **Three case studies are included in the guidelines**

  1. Automotive steel sheet, 2. Non-oriented electrical steel sheet, 3. Blast furnace slag cement

☞ When blast furnace slag cement is produced with the supply of 10,000 tons of granulated slag to cement company, 6,800 tCO_2 reduction effect is generated

※ Presumption
- Slag content of slag cement is 45%
- CO_2 emission factor of clikner is 0.8 tCO_2/t-clinker





Slag artificial reef

To restore marine ecosystem slag artificial reef has been developed

◯ It is a concrete structure made of 20% slag cement and 80% slag aggregate

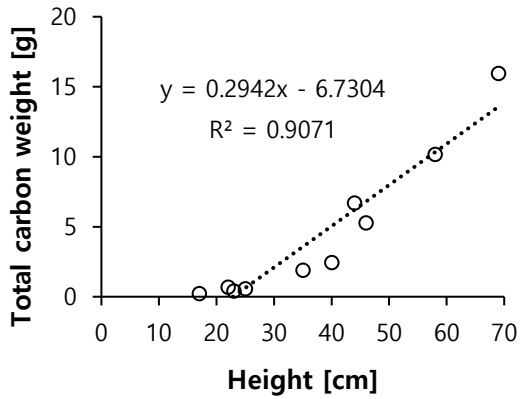
◯ Steelmaking slag contains high calcium and iron which promote seaweed growth

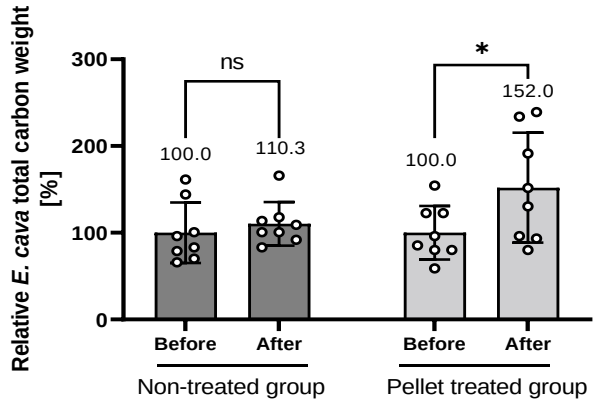
	SiO_2	CaO	Al_2O_3	T-Fe	MgO	S
Blasf furnace slag	33.1	40.0	13.7	0.4	8.6	0.3
Steelmaking slag	11.2	**41.5**	1.4	**20.0**	6.5	0.1

Steel slag and its chelating agent may contribute to the promotion of sea forestration and a subsequent increase in carbon sequestration know as ‘Blue Carbon’.

◯ The total carbon weight of seaweed was proportional to their heights

◯ 52% carbon weight increased in the slag treated group, while the non-treated group had only a 10.3% increase





* Kwon et al. Dissolved Iron from Steel Slag with Its Chelating Agent Promotes Seaweed Growth. (2022) Sustainability

Silicate fertilizer

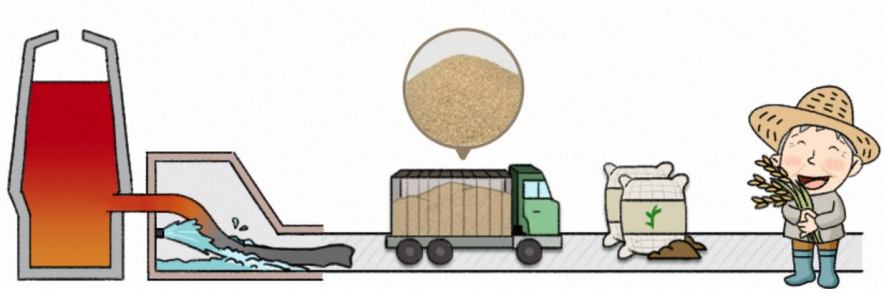
Silicate fertilizer contains a significant amount of silicate, a crucial nutrient for the growth of rice plants

○ Silica makes the stem of rice plant more than three times stronger. This directly contributes to increase crop yields and improve quality of the rice

○ Silicate fertilizer is manufactured in the form of small granules after crushing granulated blast furnace slag. 300 ktons of silicate fertilizer are used annually

※ Legal standard of silicate fertilizer (Korea Fertilizer Control Act)

: SiO_2 > 25%, Alkaline component > 40%, MgO > 2%, Cr < 800mg/kg

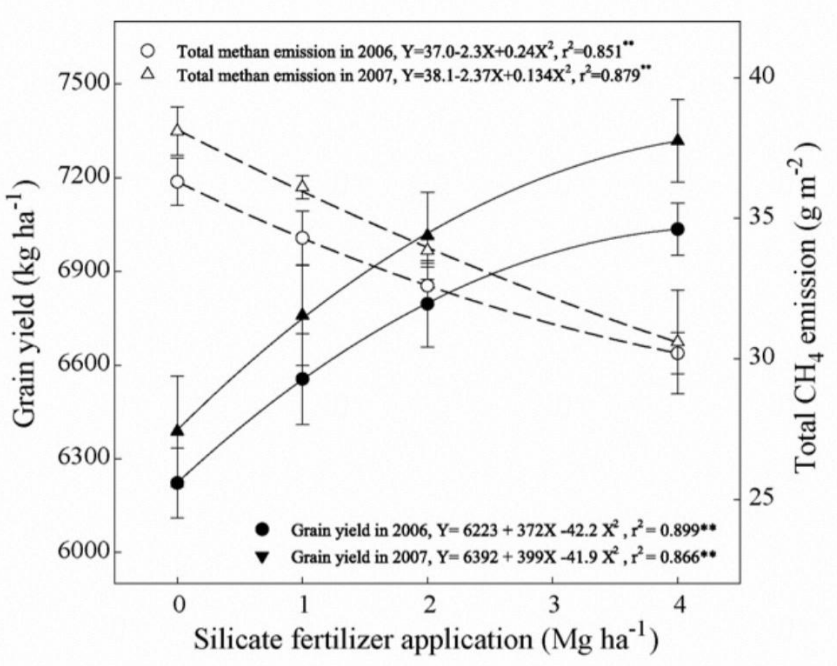


BF Granulation Silicate Fertilizer Rice cultivation

The trace amounts of iron ions (Fe^{3+}) in the slag help reduce the activity of methane-producing microorganisms

○ Wetland rice farming is one of the major sources of CH_4 emissions to the air

○ Silicate fertilizer application leads to a decrease of approximately 14% in CH_4 emissions produced during the rice cultivation process



* Ali et al. Evaluation of silicate iron slag amendment on reducing methane emission from flood water rice farming. (2008) Agriculture, Ecosystems and Environment

Environmental risk management

High-pH white-colored leachate detected at construction sites where steelmaking slag was utilized by steelmakers

○ 420 kt of EAF slags used for temporary road construction (left, Aug 2021) and
260 kt of BOF slags used as fill material for storage site construction (right, Aug 2022)

○ Environmental issues regarding slag leachate were raised by the Committee of Environment and Labor of the National Assembly

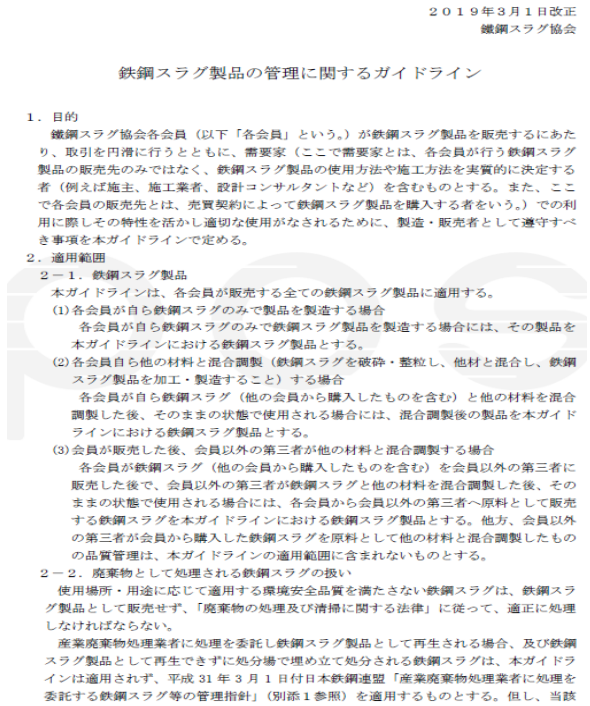
The steel industry voluntarily prepared a guideline to minimize generation of the leachate. This guideline was developed with reference to the Japanese one

○ In Japan, Slag Association published “Guideline for Iron and Steel Slag Products” in 2005.

* Steelmakers, Slag recycling companies and Recycled slag sellers (59 EA)

○ Korean steelmakers have commissioned a project to develop recycling guidelines for steelmaking slag in road and building construction (Apr 2022 ~ Feb 2023)

- Slag recycling company should visit and inspect the construction site before, during and after construction where a certain amount of slag is recycled



２０１９年３月１日改正
鐵鋼スラグ協会

鉄鋼スラグ製品の管理に関するガイドライン

１．目的
鐵鋼スラグ協会各会員（以下「各会員」という。）が鉄鋼スラグ製品を販売するにあたり、取引を円滑に行うとともに、需要家（ここで需要家とは、各会員が行う鉄鋼スラグ製品の販売先のみではなく、鉄鋼スラグ製品の使用方法や施工方法を実質的に決定する者（例えば施主、施工業者、設計コンサルタントなど）を含むものとする。また、ここで各会員の販売先とは、売買契約によって鉄鋼スラグ製品を購入する者をいう。）での利用に際しその特性を活かし適切な使用がなされるために、製造・販売者として遵守すべき事項を本ガイドラインで定める。

２．適用範囲
２－１．鉄鋼スラグ製品
本ガイドラインは、各会員が販売する全ての鉄鋼スラグ製品に適用する。
(1)各会員が自ら鉄鋼スラグのみで製品を製造する場合
各会員が自ら鉄鋼スラグのみで鉄鋼スラグ製品を製造する場合には、その製品を本ガイドラインにおける鉄鋼スラグ製品とする。
(2)各会員自ら他の材料と混合調製（鉄鋼スラグを破砕・整粒し、他材と混合し、鉄鋼スラグ製品を加工・製造すること）する場合
各会員が自ら鉄鋼スラグ（他の会員から購入したものを含む）と他の材料を混合調製した後、そのままの状態で使用される場合には、混合調製後の製品を本ガイドラインにおける鉄鋼スラグ製品とする。
(3)会員が販売した後、会員以外の第三者が他の材料と混合調製する場合
各会員が鉄鋼スラグ（他の会員から購入したものを含む）を会員以外の第三者に販売した後で、会員以外の第三者が鉄鋼スラグと他の材料を混合調製した後、そのままの状態で使用される場合には、各会員から会員以外の第三者へ原料として販売する鉄鋼スラグを本ガイドラインにおける鉄鋼スラグ製品とする。他方、会員以外の第三者が会員から購入した鉄鋼スラグを原料として他の材料と混合調製したものの品質管理は、本ガイドラインの適用範囲に含まれないものとする。
２－２．廃棄物として処理される鉄鋼スラグの扱い
使用場所・用途に応じて適用する環境安全品質を満たさない鉄鋼スラグは、鉄鋼スラグ製品として販売せず、「廃棄物の処理及び清掃に関する法律」に従って、適正に処理しなければならない。
産業廃棄物処理業者に処理を委託し鉄鋼スラグ製品として再生される場合、及び鉄鋼スラグ製品として再生できずに処分場で埋め立て処分される鉄鋼スラグは、本ガイドラインは適用されず、平成 31 年 3 月 1 日付日本鉄鋼連盟「産業廃棄物処理業者に処理を委託する鉄鋼スラグ等の管理指針」（別添１参照）を適用するものとする。但し、当該

New limit values for Soil Conservation Act

Heavy metal components in soil are controlled based on total content according to the Soil Conservation Act

◯ The limit value for fluoride in soil was 400 ~ 800 mg/kg, which was lower than that (400 ~ 4,000 mg/kg) of other countries

◯ Due to the low limit value, more cost are required to remediate soil and sometimes land development project was delayed

Steel industry has proposed a revised value for fluoride in soil

◯ The revised value was based on the result* of environment risk assessment and the fluoride content in steelmaking slag

* The fluoride limit was 401 mg/kg for Region 1 and 2,505 mg/kg for Region 2

◯ Active communication with Ministry of Environment and external experts

Ministry of Environment amended the law to ease the fluoride limit in soil after collecting opinions from stakeholders and implemented it from December 2024

< Worrisome levels of soil contamination (mg/kg) >

Substance	Region 1	Region 2	Region 3
Cd	4	10	60
Cu	150	500	2,000
As	25	50	200
Hg	4	10	20
Pb	200	400	700
Cr^{6+}	5	15	40
Zn	300	600	2,000
Ni	100	200	500
F	800 (400)	1,300 (400)	2,000 (800)

( ) : Level before amendment in December 2024

- Region 1 : Field, orchards, farm, residential areas, playground
- Region 2 : Forests, warehouse sites, amusement parks
- Region 3 : Factory sites, parking lots, roads, railways

Thank you very much!

Rick Lim
POSCO-Europe
jt.lim@posco-inc.com

5.–6. MARCH 2025

ESTEP Focus Group Circular Economy & FEhS-Institute

ESTEP
European Steel Technology Platform

INSTITUT FÜR BAUSTOFF FORSCHUNG
FEhS

posco