IRF-IC 5th Webinar

Sustainable Alternative Industrial Waste Materials for Infrastructure Development

Sustainable Applications of Iron and Steel Plant Wastes in Infrastructure Development

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Research and Development

JSW
Better Everyday

Steel Plant Wastes

- The iron and steel making processes generate huge amount of wastes in form of **slags, dusts and sludge** .
- The disposal or recycling of these materials is a major concern for the steel industry.
- With increasing capacity of steel production, significant efforts and investments have been made into research over the years to develop the **processing technologies** which enable re-use them either directly or through development of **new products**.

- It is the time to convert the waste disposal and treatment concepts into **Integrated Waste Management** in steel plants.

Sustainability

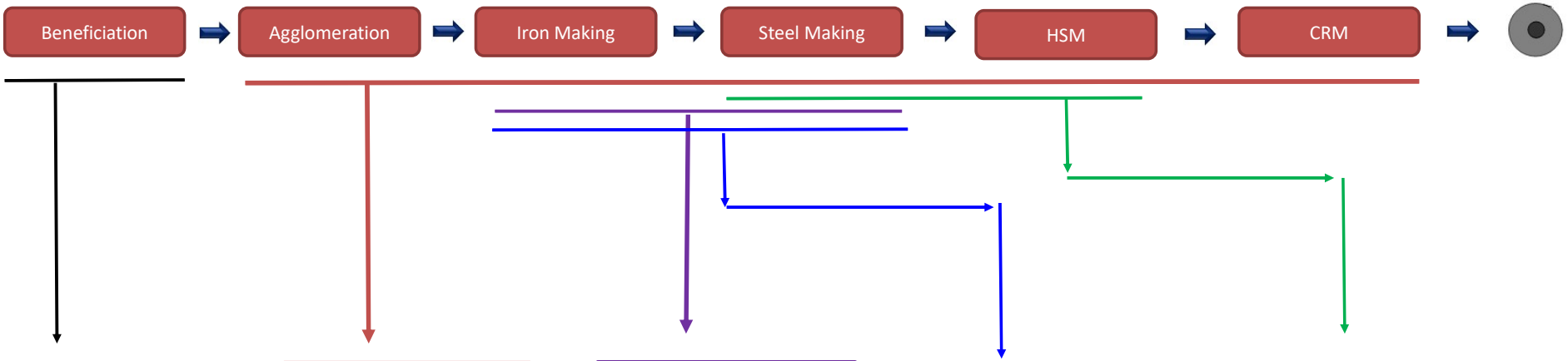
- The requirement of a sustainable technology by meeting the needs of our present industry **without compromising the future growth** is really a challenge to the steel Industry today.

- With growing shortages of energy and materials, waste is now treated as a potential resource complying with Environmental legislation and regulations and the **economics of disposal**.

- Due to intensive reutilization of the wastes some of the solid wastes are now increasingly being referred as **'by-products'**.

- The technologies are being developed to economically convert wastes of steel plants into wealth also provide new **business opportunities** for prospective entrepreneurs.

Wastes in Steel Plant



Tailings

20 - 25 %

Dusts

40 - 50 Kgs/T

Sludge

50 - 60 Kgs/T

Slag

600 - 650 Kgs/T

Scales

15 -18 Kgs/T

Wastes in Steel Plant

Tailings

High Moisture > 60%

Fine size < 150 um

Fe 30 – 45 %

High SiO_2 & Al_2O_3

Dusts

Fine size < 1 mm

Composition varies in each location

High CaO, FeO, C

- High Zn
- Low Zn

Sludge

High Moisture > 20%

Fine size < 1 mm

Fe 40 – 50 %

Composition varies in each location

High CaO, FeO

- High Zn
- Low Zn

Scales

High Moisture > 15%

Fine size < 5 mm

Fe 60 - 70%

No impurties

Slag

Iron and steel slag different treatments

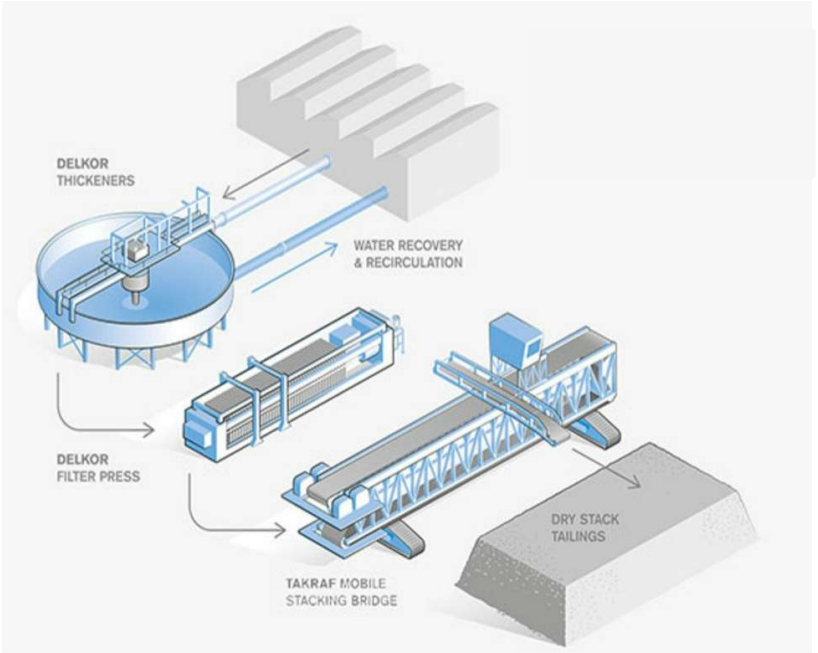
3 types of steel slag

Met content in steel slag

- Iron Slag
- Steel Slag
  - De- S
  - LD
  - LHF

Tailing Treatment

Press Filters to De-watering

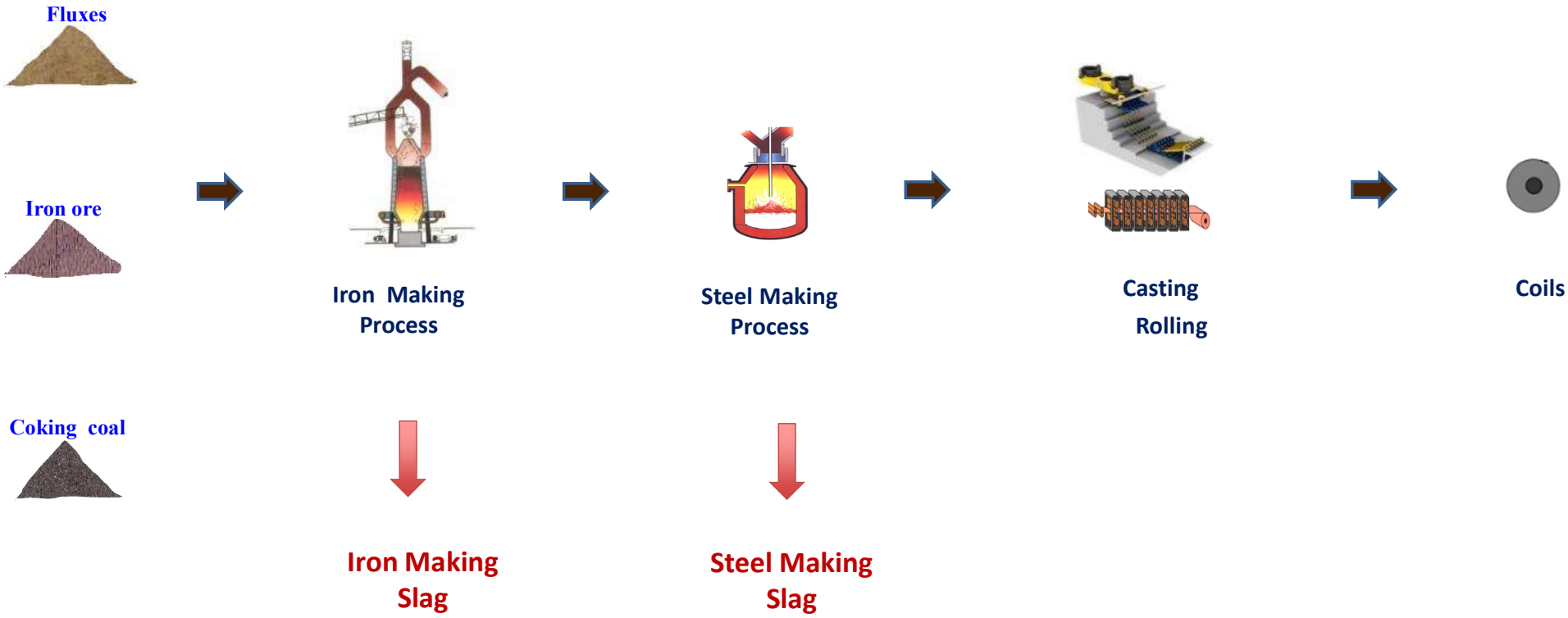


Dry Disposal

Mine Backfilling

Moisture : 60 % → < 20%

Slag Generation



Broadly two different types of slags are generated in steel plants

Environmental Friendly Aggregates

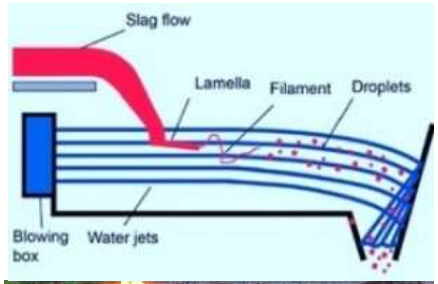
Fine Aggregates or Sand

Coarse Aggregates

Iron Making Slag

Technologies

Blast Furnace
COREX



- Mostly Granulated
- Dose not have carryover metal
- Does not have Iron oxide
- Cementious – used for cement making (Slag Cement)
- **100 % consumed – no issues to most steelmakers**

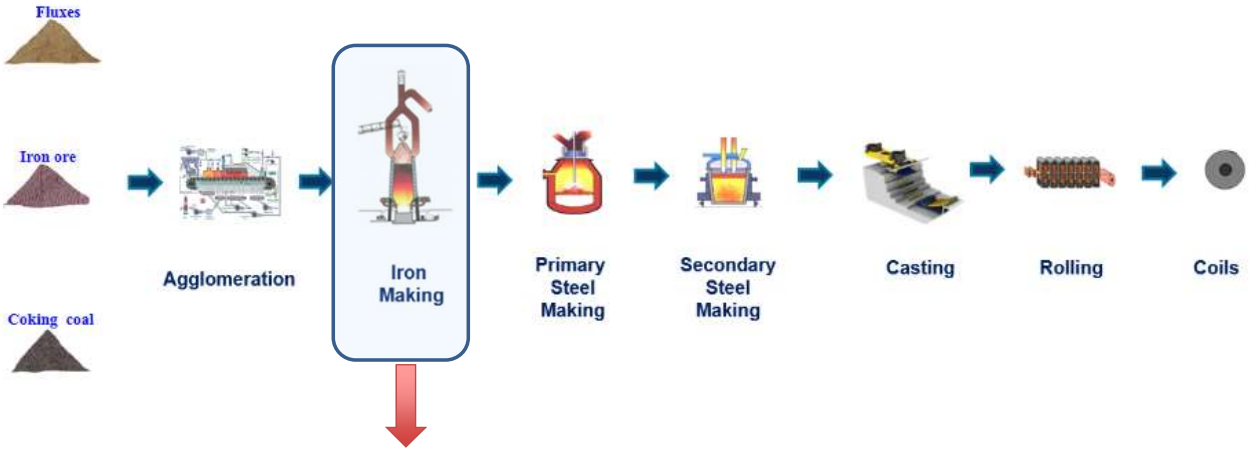
Technologies

BOF / LD
EAF
EOF
Conarc
Induction Furnace

Steel Making Slag

- Mostly Pit Cooled
- Have carryover metal
- Have Iron oxide
- Non-Cementious – not suitable for cement making
- **Disposal is concern – most used for land filled**

Iron Making Slags – Existing Technologies



Similar slags are generated from all Process Variants

Blast Furnace

COREX

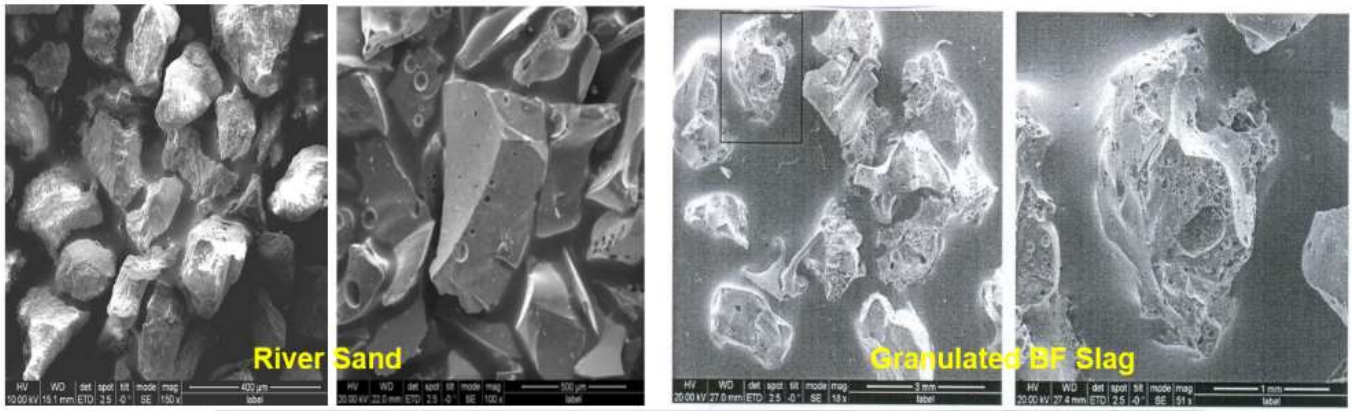
FINEX

Granulated
(90 - 95 %)
→ Cement Making (PSC)

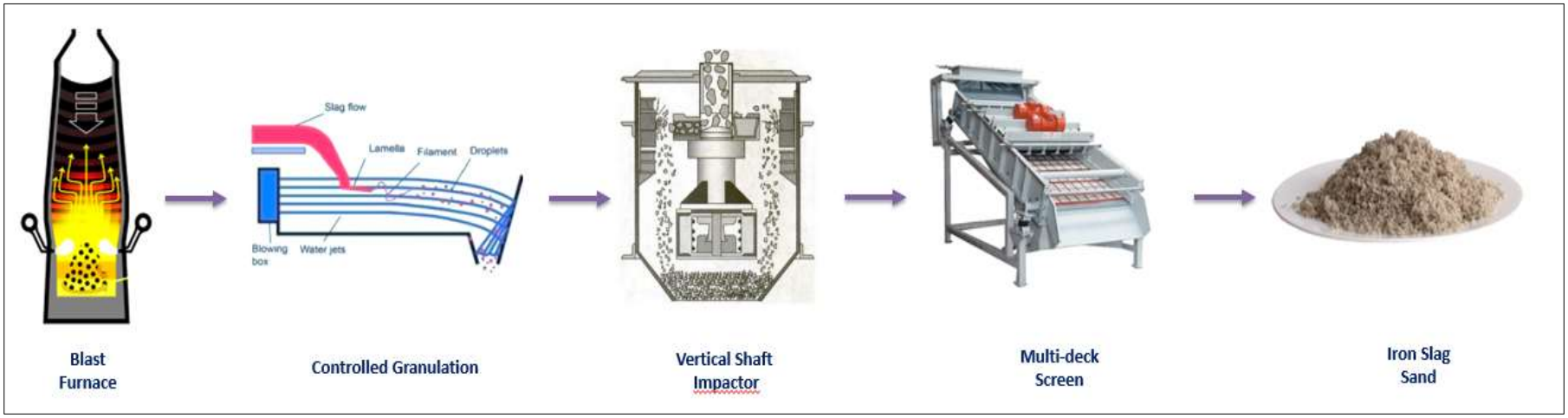
Air Cooled / Dry Pit Slag
(5 - 10 %)
→ Land Filling / Dumping

Iron Making Slag

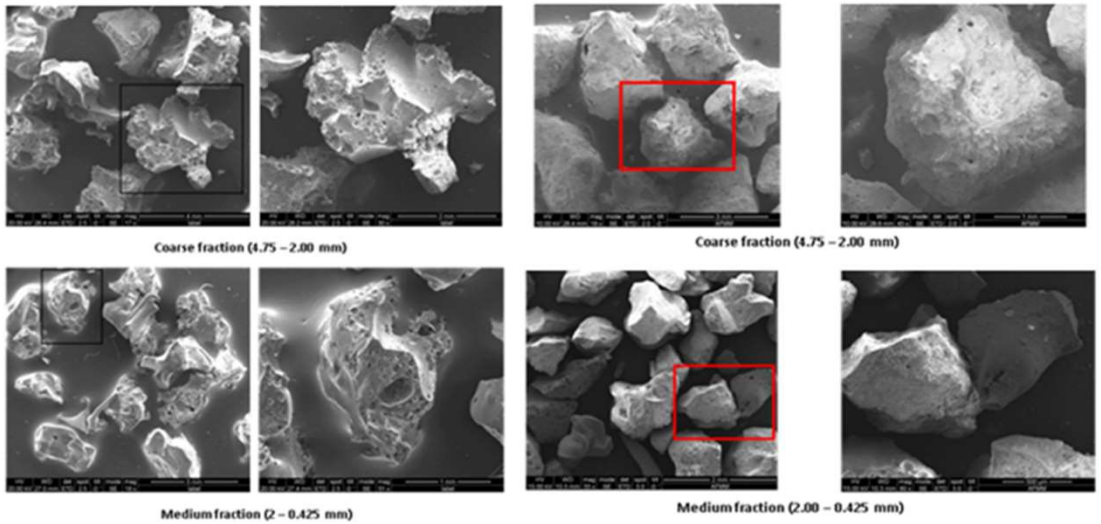
PROPERTIES	RIVER SAND	GBFS
Size	IS 383 - Zone II / Zone I	IS 383 - Zone II / Zone I
Deleterious Material	0.2 %	Nil
Soundness	Good	Good
Density, Kg/m3	1400 - 1700	1000 - 1100
Sp Gravity	2.6 - 2.8	2.3
Water Absorption	1 – 3 %	4 -6 %



Lower density in slags is due to its vesicular structure with presence of micro pores

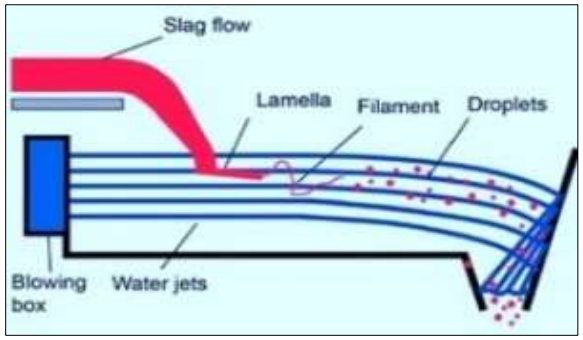


Granulated BF Slag

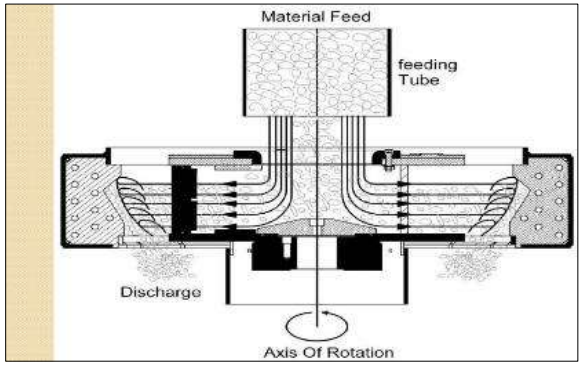


Processed Granulated BF Slag

Iron Making Slag Sand



- **Step 1: Altering granulation parameters**



- **Step 2: Shaping and Screening**

India's First Iron

Slag Sand Plant

DRY SLAG GRANULATION

Dry slag granulation is the future technology of granulation

First Time in World

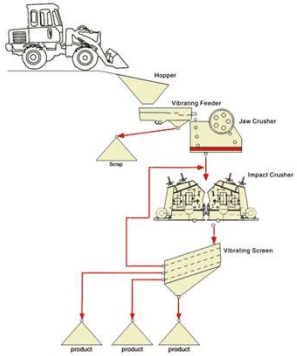
Technology	Wet granulation	Dry granulation
Medium	Water	Air
Water Consumption	0.6 – 0.7 Nm3/T	0.1 – 0.2 Nm3/T
Operational cost	1	0.75
Capital cost	1	0.80
Heat Recovery	NA	Possible
Slag handling	Wet Condition	Dry Condition
Steam Emissions	Yes	No
Corrosion	Yes	No
Glassy Phase	> 90 %	> 90%
Size	< 5 mm	< 5 mm
Application	Cement making	Cement making

Dry Pit Slag – New Applications

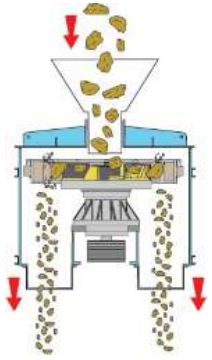
Ideal Air Cooled Dry Pit Slag

Existing Water Cooled
Dry Pit Slag

Water is sprayed over the molten slag to cool it fast, results in foaming and porous slag



Crusher + Screen + Pug Mill



Jaw crusher + Vertical Shaft Impactor + Screen

To be used as coarse aggregate in lower layers of roads mixed with Steel Slag

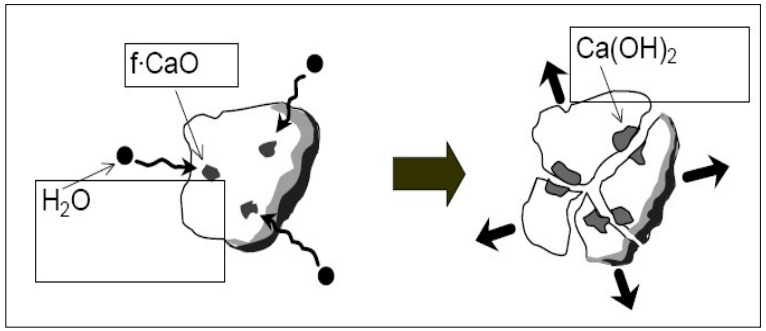
NH-67: Hosapete to Ballari: Total Length 95 KM

To be used sand as replacement of river sand

Steel Making Slag

Issues :

- Presence of Metal
- Irregular shape
- Wide range of size
- Higher density
- Higher amount of fines
- Expansive Nature



Expansion tendency is due to free lime/periclase pockets in slag, which when crushed to finer sizes, gets exposed and aged naturally.

Existing Solutions

Natural Ageing

Storage for land for a period of 1.5 - 2 yrs

Dry and Wet Cycle Aging

Frequent water spraying on slag heaps 3 – 6 months

Open Steam Ageing

Steam Injection into slag heap for 5-7 days

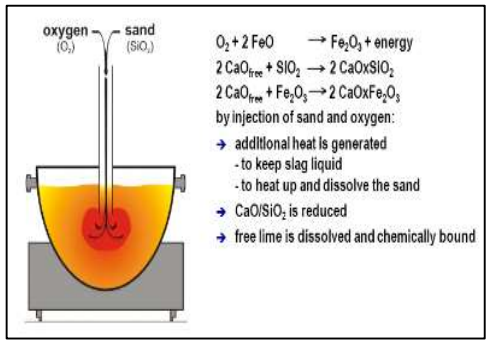
Pressurized Steam Ageing

Steam Injection into slag in closed system for 4-6 hrs

Steam Box Technology

Subjecting slag with water and steam in closed box during solidification

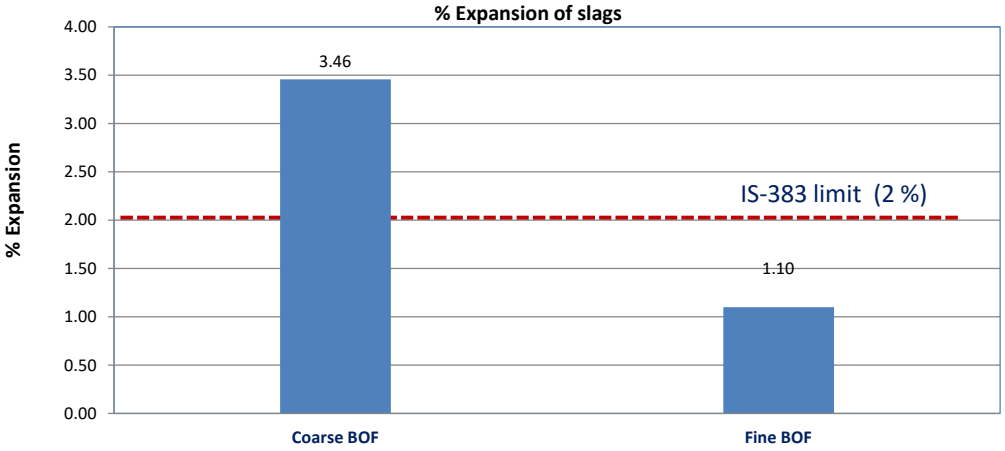
Chemical Stabilization of Molten Slag



Steel Making Slag

Expansive

Non- Expansive



Comparison of Expansive Behaviour as per IS-383

World's First Steel

Slag Sand Plant

Customised Process

Starts from Steel Melting shop

In-house designed circuit – Assembled Units

No Such Full Scale Set-up Reported

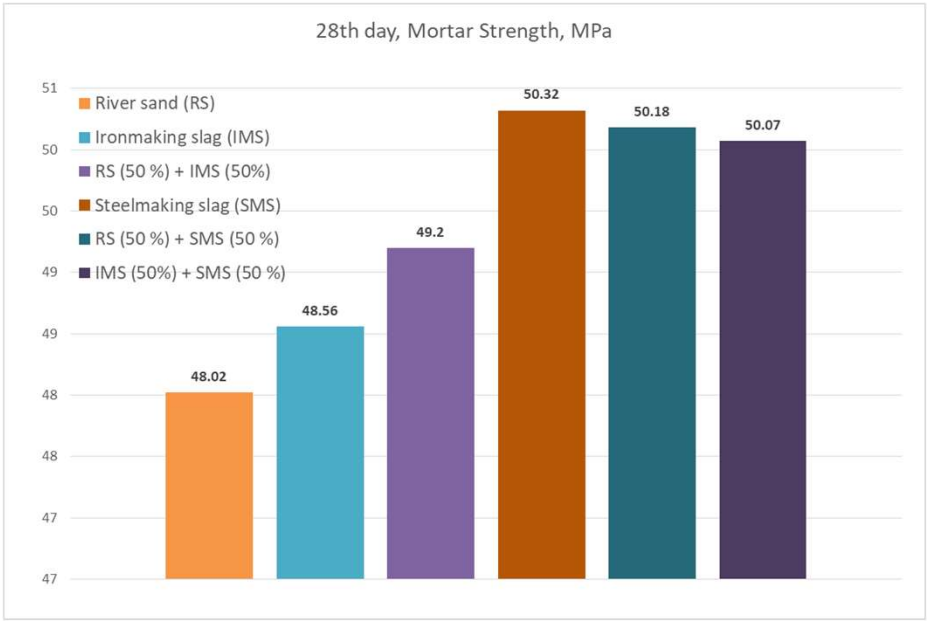
No Rejections

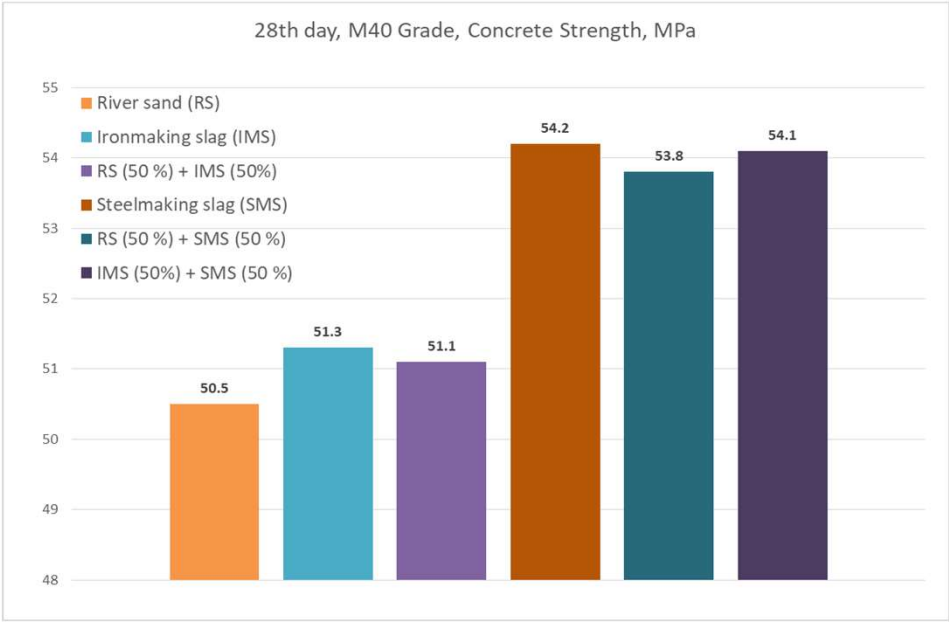
Applications for all components

First of its kind in the World

Test Results





Iron slag sand manufacturing unit

Steel slag sand manufacturing unit

Fine Aggregates Available

From
Rivers

From
Mountains

Slag Sand

Eco-Friendy

Saves Natural Resources

From
By-Products

Applications of Slag Sand

Advantages

- No Expansion Issues
- Better strength than river sand
- Environmental friendly alternative.
- Controlled Physical and Chemical Properties.
- No deleterious material.
- Available through out the year.
- Graded products to meet specific needs.
- Suitable for Roads, Concrete, Plaster, Mortars, RMC Plants etc.

Applications

- Plain Concrete
- Reinforced Concrete
- Standard Ready-Mix Concrete
- Dry Lean Concrete
- Pavement Quality Concrete
- Rapid-setting Concrete
- Asphalt Concrete

Flooring for heavy loads

Used in all three Layers

PQC – Pavement Quality Concrete

DLC –Dry lean Concrete

GSB – Granular Sub-Base

NH-67: Hosapete to Ballari: Total Length 95 KM

Concrete road made up of slag aggregates (Fine and Coarse)

Steel Slag Usage in Roads

Ministry of Steel Sponsored Project

National Guidelines released on 29th June 2024 by CRRI

Approved to be used as aggregates in Roads

Table 9.1: Engineering Properties of Processed Steel Slag Aggregates for Road Application

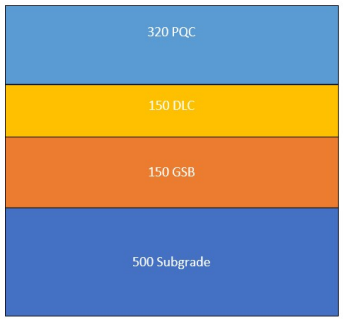
S.No.	Properties	Typical Range of Processed Steel Slag Aggregates			Permissible Limits for Processed Steel Slag Aggregates			Test Method
		BOF	EAF	CONARC	Surface Course (DBM, BC, DLC and PQC)	Base (WBM & WMM)	Sub-base (GSB)	
1	Aggregate Impact Value % (Dry Condition)	10-22	12-20	10-20	Max. 27	Max.30	Max.30	IS 2386 (Part IV)
2	Aggregate Impact Value % (Wet Condition)	12-24	14-18	12-16	NA	Max. 30	Max. 35	IS 5640
3	Los Angeles Abrasion Resistance, %	11-18	10-14	10-14	Max. 30	NA	NA	IS 2386 (Part IV)
4	Water Absorption Test %	1-2	0.5-1.5	0.5-1.5	Max. 2	Max. 2*	Max. 2	IS 2386 (Part III)
5	Specific Gravity	2.93-3.20	2.95-3.4	2.95-3.4	Permissible Range 2.9- 3.45			IS 2386 (Part III)
6	Combined Flakiness & Elongation (FI+EI) Index %	8-22	10-21	10-21	<30	<30	<30	IS 2386 (Part I)
7	Soundness Test - Sodium Sulphate in %	0.2-1.8	2-4	2-4	< 12	< 12	< 12	IS 2386 (Part V)
	Magnesium Sulphate in %	0.3-2.1	3-5	3-5	< 18	< 18	< 18	
8	Stripping Value Test % (Bitumen coating retention)	98-99	99-99.5	99-99.5	Min. Retained coating 95	NA	NA	IS 6241
9	Iron unsoundness ** %	Nil	Nil	Nil	< 1	< 1	< 1	IS 383 (Annexure D)
10	Iron Stain Index Test*** (Staining from Iron compound)	0-40	0-40	0-40	<60***	NA	NA	ASTM C 641-07
11	Volumetric Expansion Test, %,	1-2	0.8-1.40		< 3			EN:1744-1

Benefits of Steel Slag Aggregates

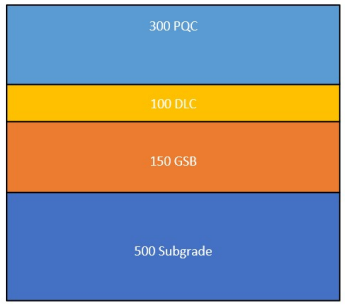
- Reduction in overall Bituminous Road Thickness by 30 to 40 %
- Conservation of around 80000 tons of Natural Aggregates for construction of 1 Km six lane road
- Reduction in construction cost by 40 to 45 % in Bituminous and Cement Concrete Steel Slag Road
- Improved Durability of Road by 4 to 5 times
- Negligible Maintenance cost
- Reduction in Green House Gases Emission by 48 % by substituting natural aggregates with processed steel slag aggregates
- Cheaper, economical option of Natural Aggregates for Road Construction

WASTE TO WEALTH
Swachh Bharat Unnat Bharat

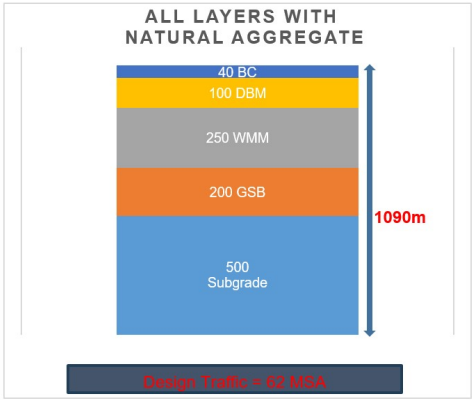
Saves Cost and Environment



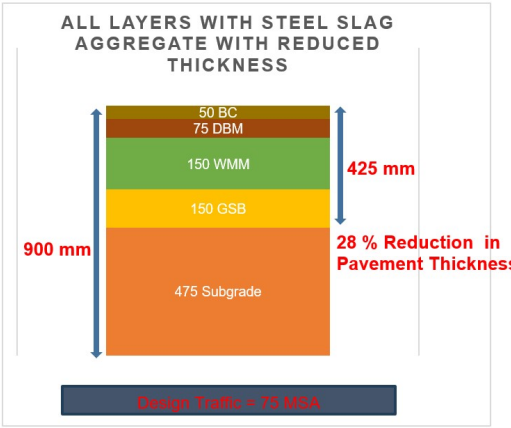
CONVENTIONAL CONCRETE ROAD



STEEL SLAG ROAD WITH REDUCED THICKNESS

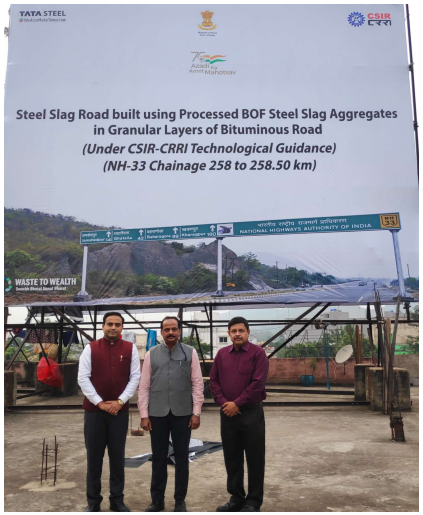


CONVENTIONAL ASPHALT ROAD



STEEL SLAG ROAD WITH REDUCED THICKNESS

On-Site Applications



Steel Slag being tested to build national highways

1 min read • Livemint

Updated: 15 Mar 2023, 07:26 PM IST

This initiative will help to address challenge of shortage of material used in development of the national highways, and could replace natural aggregates such as sand, gravel, or crushed stone with the waste material from the steel industry, road transport ministry said

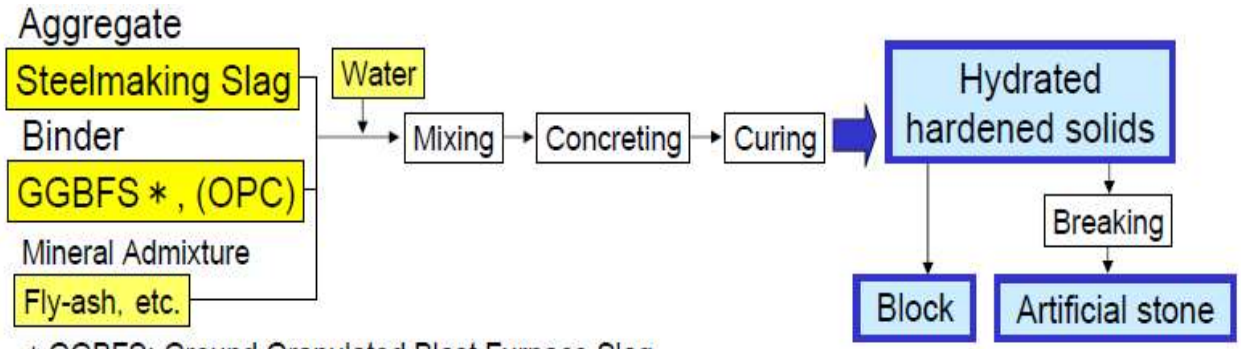
The NHAI permitted CRRI to construct 1 km long trial patch in Raigarh district for PQC of Panvel – Indapur section of NH 66 near Mumbai where 100% natural aggregates were replaced by steel slag derived aggregates. The results from the trial have been encouraging.

Slag Bound Roads

Building of self-hardening road pavings

A special advantage of slag mixtures resides in their hardening by carbonic and/or hydraulic reactions without using a binder like cement or bitumen.

Stone Blocks and Breakwaters



＊GGBFS: Ground Granulated Blast Furnace Slag

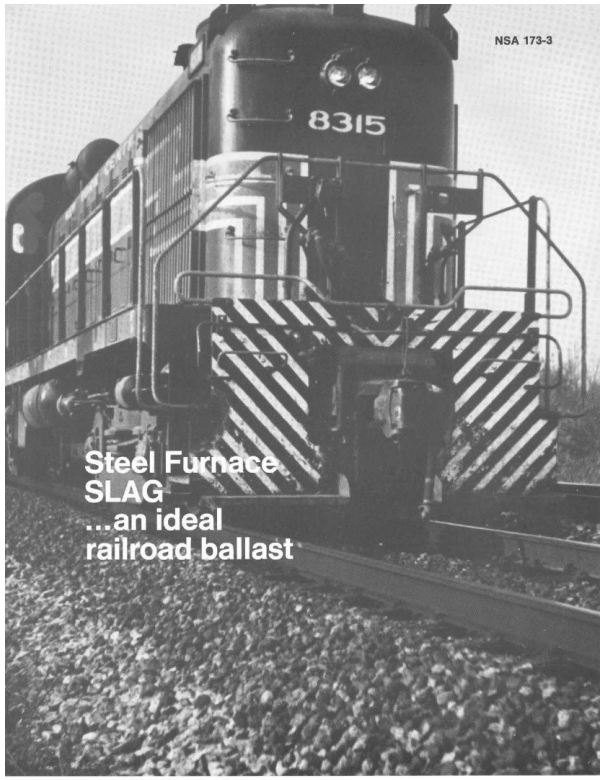
Coastal levee block

Artificial stone (for port construction work, etc.)

Break-water Block

Railway Ballasts

High angle of internal friction and high aggregate interlocking characteristics



- Steel Slag complies with the requirements of:
  - American Railway Engineering Association (AREA)
  - Federal Specification SS – S – 449
  - Brazilian Standard Association (ABNT) - NBR 5564
  - Canadian National Railways (CNR) Specification 12 – 22, Slag Ballast
  - EAF Slag selected for use as railway ballast in Canada

Conclusions

- Indian steel plants should recognize that if they are to remain competitive they **must take a fresh look at ways to minimize waste/prevent** pollution arising from their production processes and supporting activities.

- In present scenario, Steel plants have to aim for converting the waste management system into a profitable business to achieve **“zero waste concept”.**

- Proper management of waste and its effective reutilization will **convert waste into wealth.** Therefore, waste treatment and its reuse be made as an essential process step in almost all integrated steel plants.


Thanks .....