Sustainability and Circular Economy in Indian Cement and Construction Industry

High-Level 12th Regional 3R and Circular Economy Forum in Asia-Pacific

Dr L P Singh
Director General

National Council for Cement and Building Materials
(Min. of Commerce and Industry)

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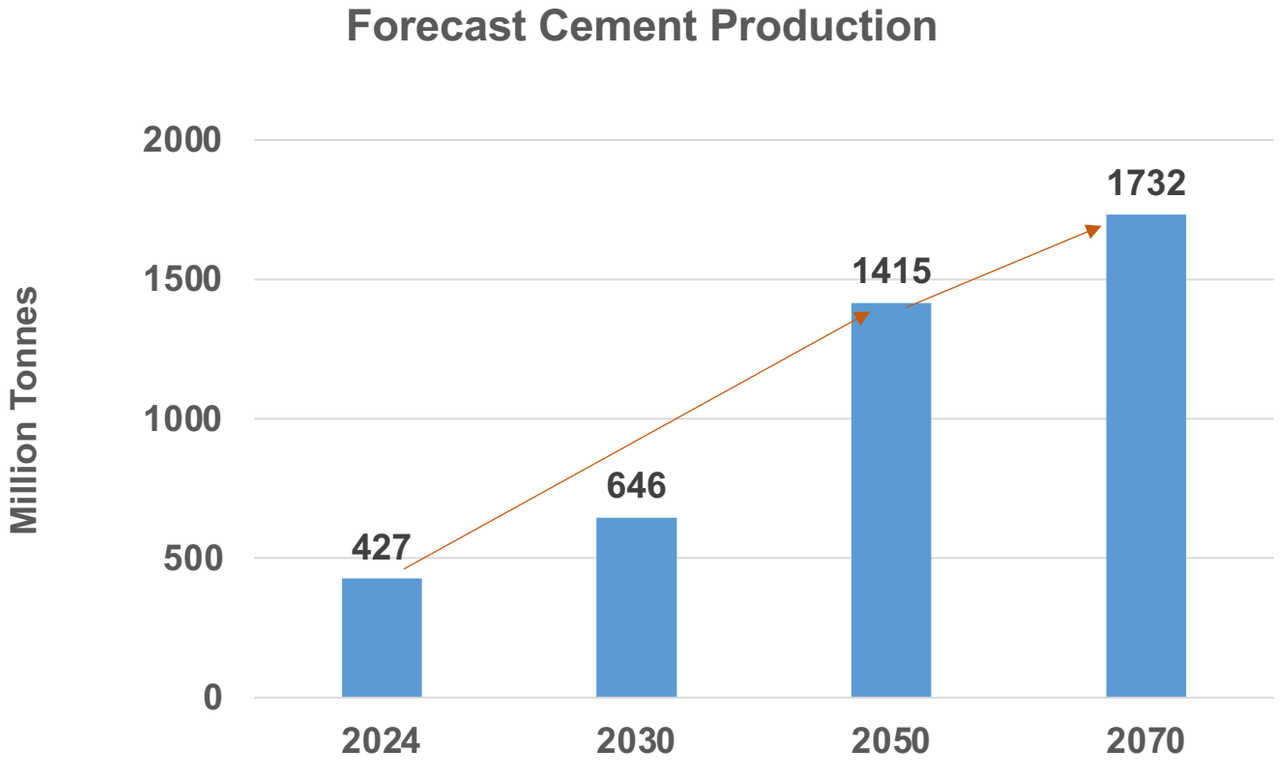
INDIAN CEMENT INDUSTRY

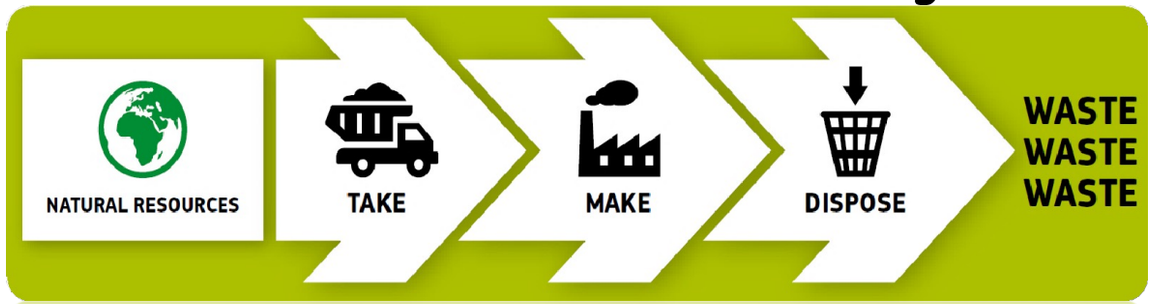
- One of the core industries of India
- 2nd Largest in the world after China
- Cement production of 427 million tonnes in 2023-24
- Installed capacity of about 622 million tonnes per annum
- Per capita cement consumption

  ~290 kg v/s world average ~540 kg

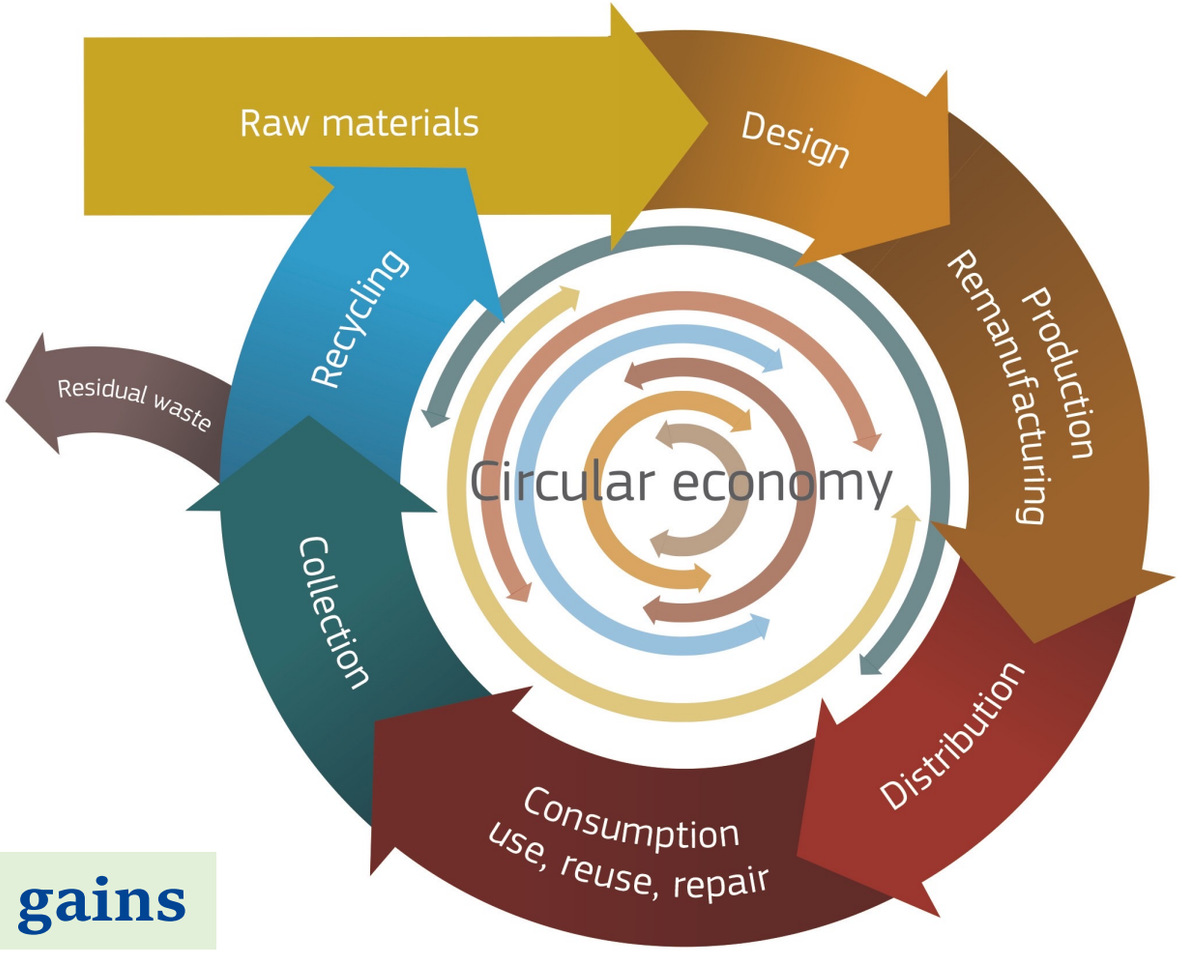
  - 159 Integrated Cement Plants
  - 05 Clinkerization Units
  - 128 Grinding Units



From a Linear Economy…



… to a Circular Economy



Maintaining the value of products, materials and resources in the economy as long as possible while minimising waste generation

For economic, social and environmental gains

Natural Resources (Coal, Limestone)

Product (Power Generation)

Waste (Fly Ash, FGD Gyp.)

Fly Ash

Linear Economy

Natural Resources (Phosphate rock)

Product (Phosphoric Acid)

Waste (Phospho Gypsum)

Legacy Gypsum Stack

Natural Resources (Coal, Limestone)

Product (Power Generation)

Waste (Fly Ash, Gypsum)

Natural Resources (Phosphate rock)

Product (Phosphoric Acid)

Primary Industry

Circular Economy

Natural Resources (Limestone, Coal)

Resource (Fly Ash, Gypsum)

Product (Cement)

Secondary Industry

Flyash Scenario in India

Green

Grey

1994

Cement and Construction Industry – Central role in Circular Economy Framework

Cement Industry utilizes wastes/by-products from:

- **Thermal Power Plants (Fly Ash & FGD Gypsum)**
- **Iron & Steel Industry (BF slag & LD Slag)**
- **Fertilizer Plants (Phosphogypsum)**
- **Other Industries like**
  - **Paper Industry (Lime Sludge)**
  - **Aluminium Industry (Red Mud, SPL)**
  - **Zinc Industry (Jarosite)**
  - **Ferrochrome (FC Slag)**
  - **Leather Industry (Leather sludge)**
  - **Marble Industry (Marble Slurry)**
  - **Petroleum Refinery (E-cat waste)**
  - **Mining Waste (Low Grade Limestone)**
  - **C&D waste (Aggregates)**

Present Scenario of Cement Types

Binary Blended cements :

- Portland Pozzolana cement – Flyash based (IS 1489 : Part I - 2015)
- Portland Pozzolana cement Calcined clay based (IS 1489 : Part II – 2015)
- Portland Slag Cement (IS 455 – 2015)

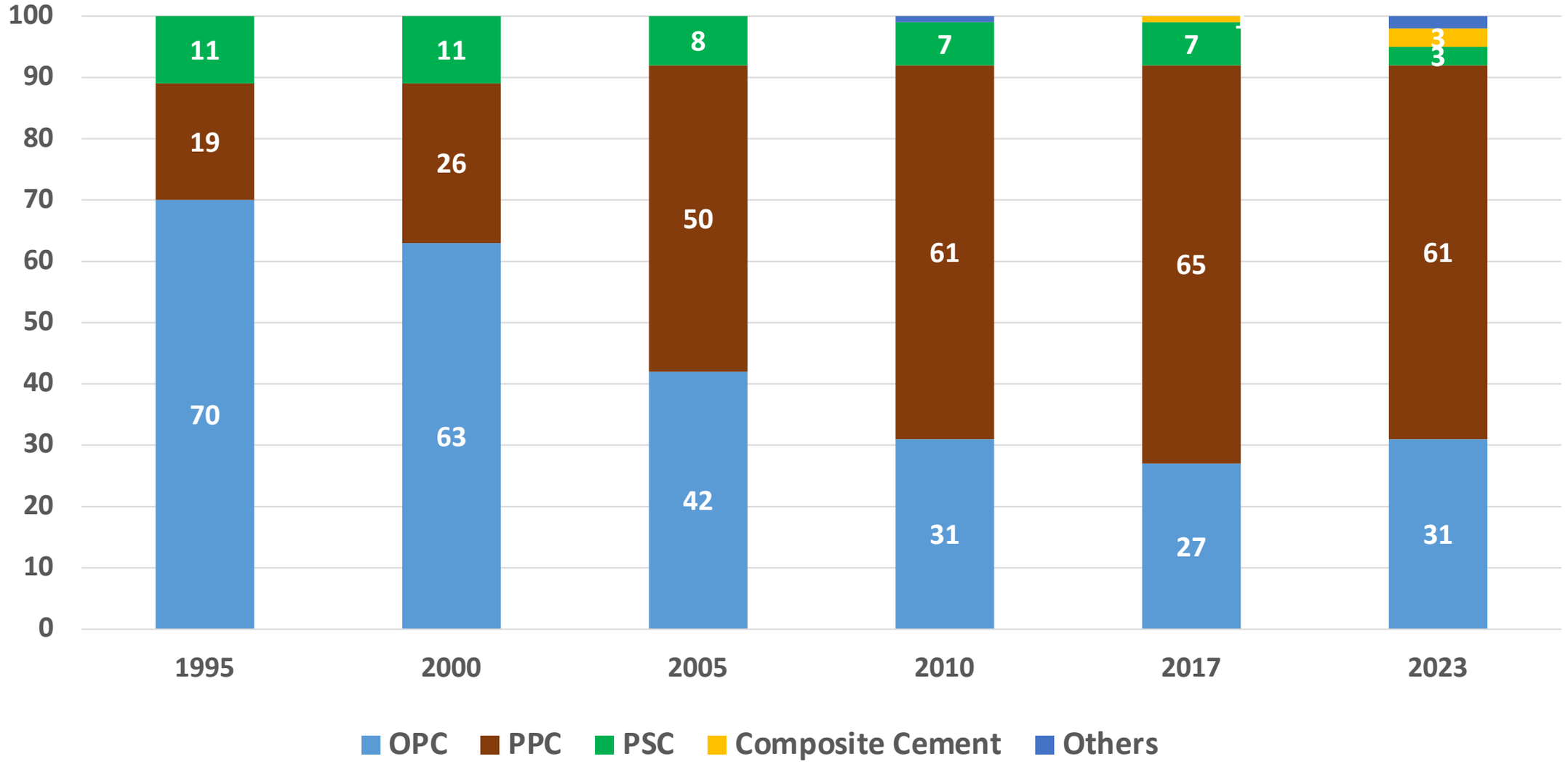
Ternary Blended Cements:

- Composite Cement (IS 16415 : 2015) – Clinker + FA + Slag + Gypsum
- Limestone Calcined Clay Cement (LC3)
- Portland Composite Cement –
  - Clinker + FA + Limestone + Gypsum
- Portland Limestone Cement – Clinker + Limestone + Gypsum

Quaternary Blended Cements (Under Development):

- Masonry Cement (IS 3466 : 1988) – Clinker + FA + Limestone / Dolomite / conglomerate + Slag + Gypsum.
- Composite Cement – Clinker + FA + Slag + Limestone + Gypsum

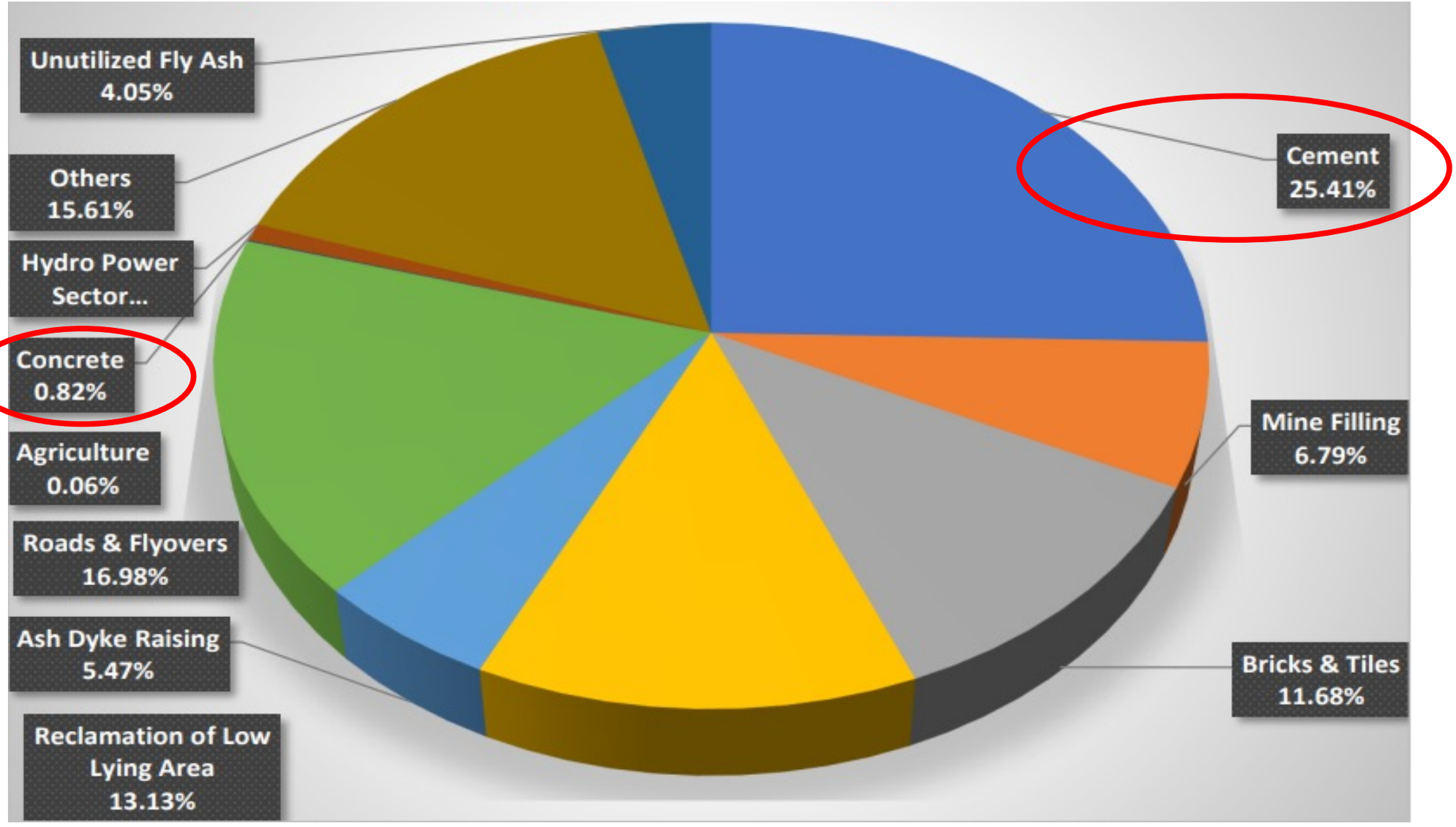
Cement Product Mix in India



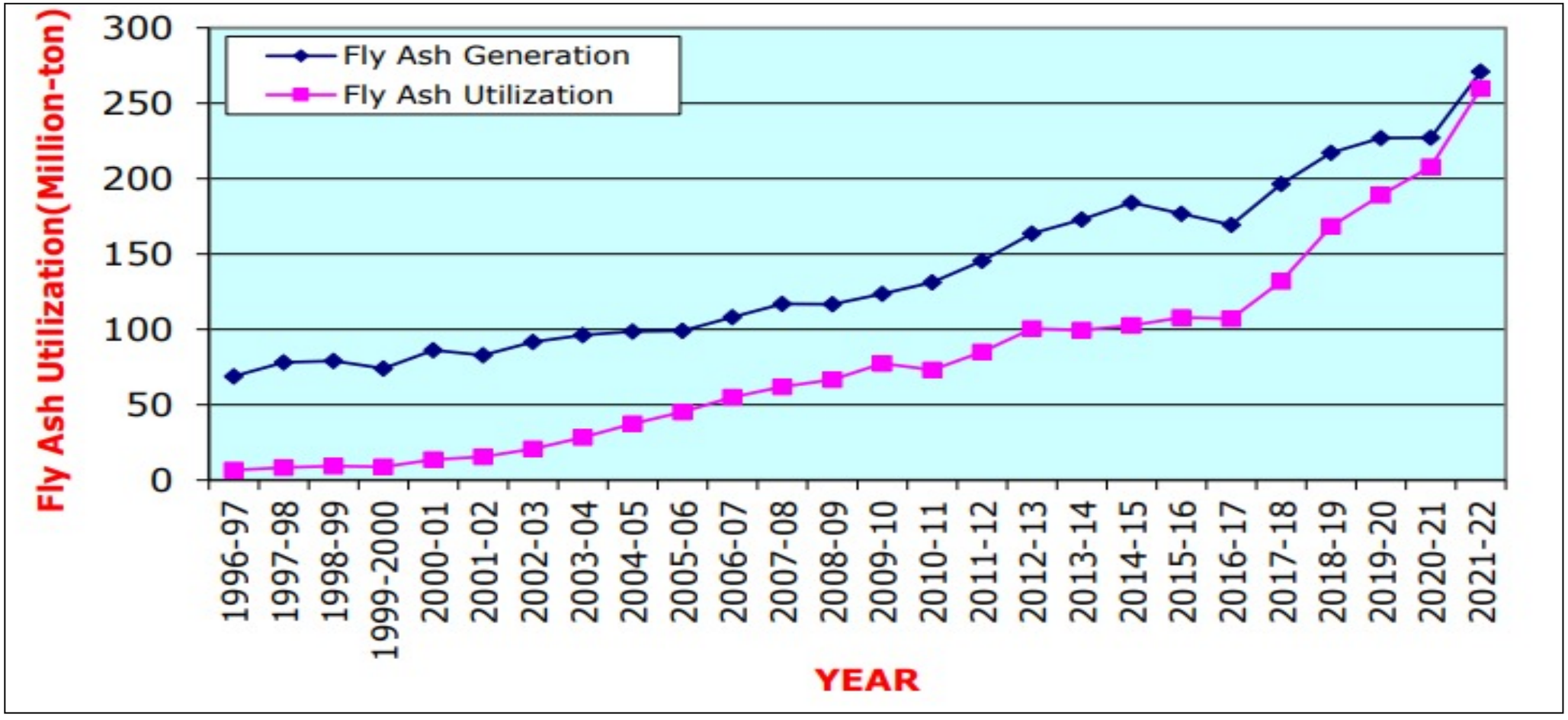
Supplementary Cementitious Materials - 1. Fly Ash

Challenges / Issues – Cement Industry
Fly Ash Generation & Utilization In India

Fly Ash Generation in 2021-22: 270 Million Tonnes



Status of Utilization of Fly Ash



Source: Report on Fly ash generation at Coal/Lignite based thermal power stations and its utilization in the country for year 2021-22 by CEA.

Enhancing Fly Ash Utilization in Cement Industry

At Present Fly Ash Utilization in Cement Industry is around 31%.

Steps are being taken up to:

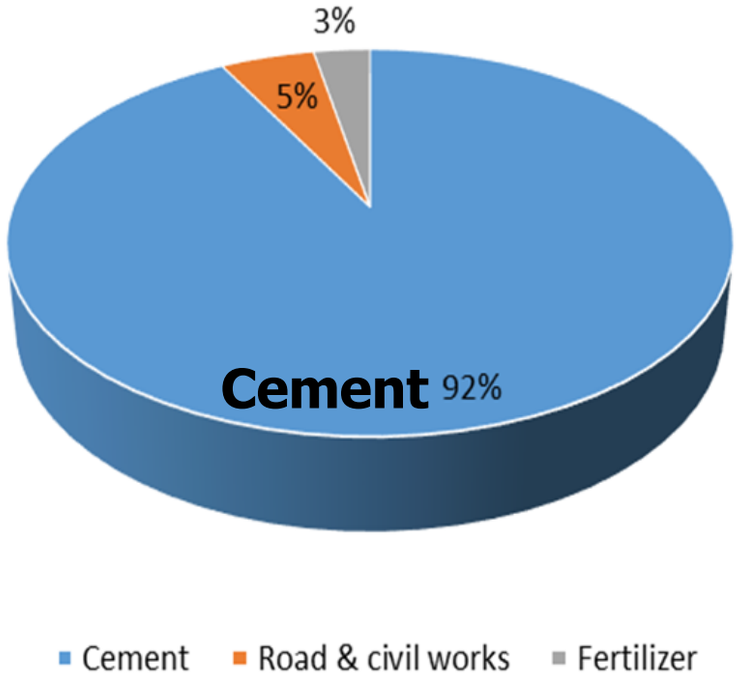
- Enhance Fly Ash addition from the existing limit of 35% to 40% in Portland Pozzolona Cement (PPC) - ***Recommendations submitted to BIS for codal modification***

- Utilization of Coarse Fly Ash (200-250 m^2/kg) in cement manufacture – ***Durability studies are being undertaken***

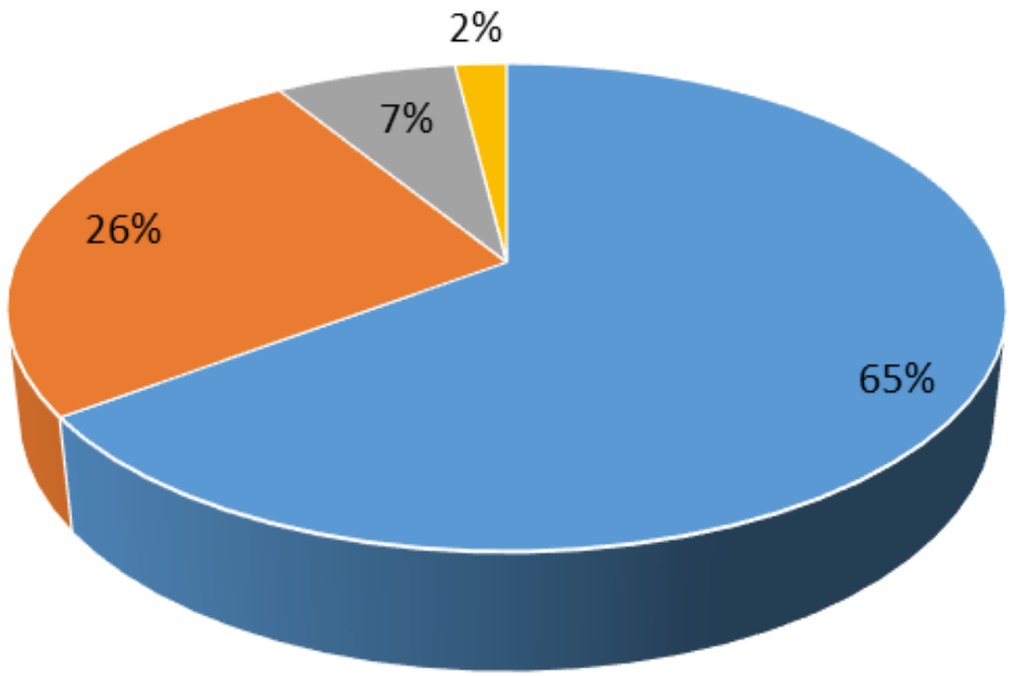
- Development of Portland Composite Cement based on Fly Ash and Limestone - ***Recommendations submitted to BIS for standard formulation***

Supplementary Cementitious Materials - 2. Blast Furnace Slag

Sector-wise Use of BF Slag in India



Sector-wise Utilization Level of Steel Slag/LD Slag in India



Achieving Circular Economy in Gypsum

Two by-products/resource streams of gypsum due to their existing generation in large quantities/estimated generation in near future

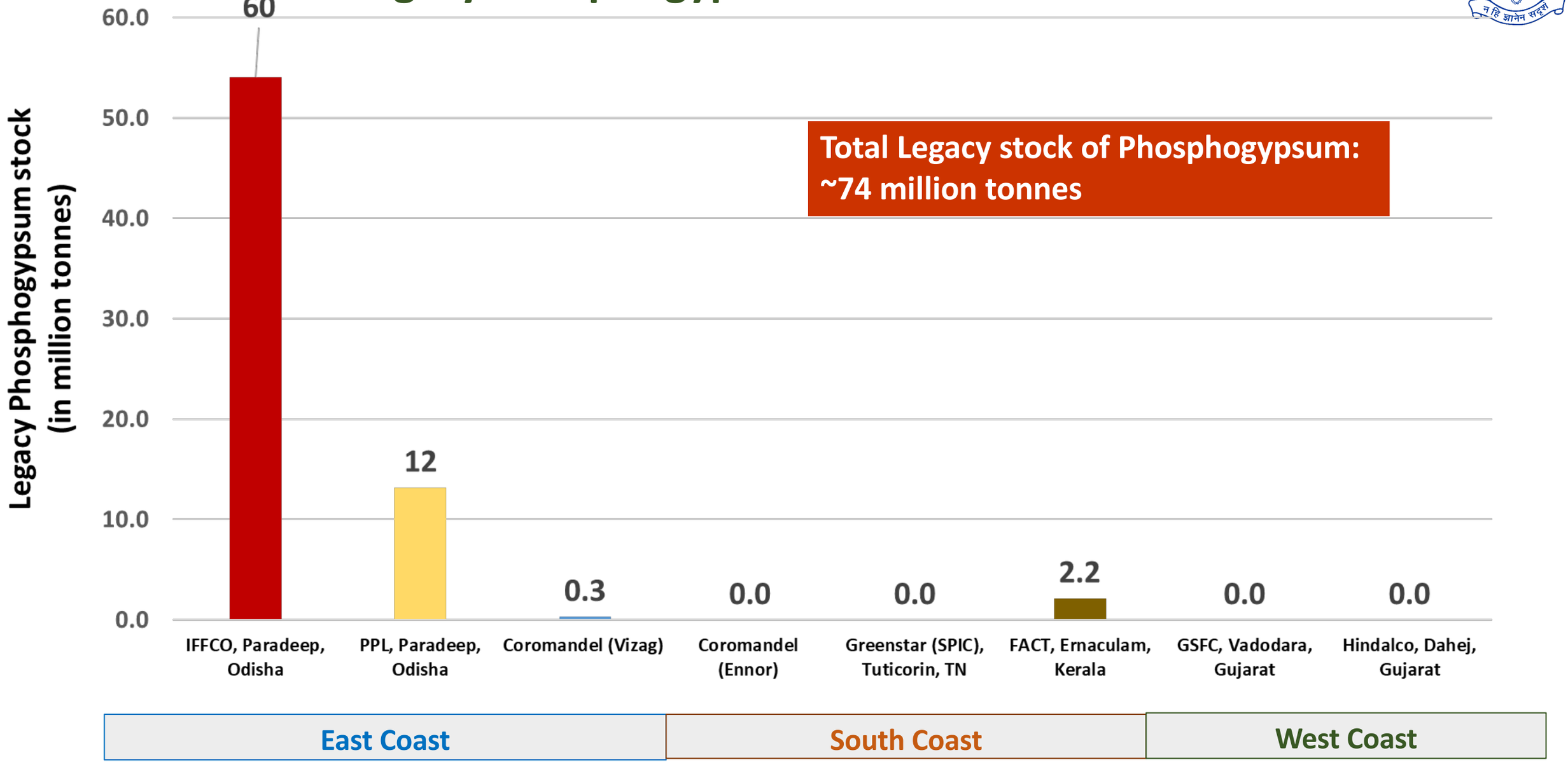
- **Phosphogypsum from fertilizer units**
- **Flue Gas Desulphurization (FGD) gypsum from thermal power plants**

Phosphogypsum (PG): Generation and Legacy Stock

Indian Scenario:

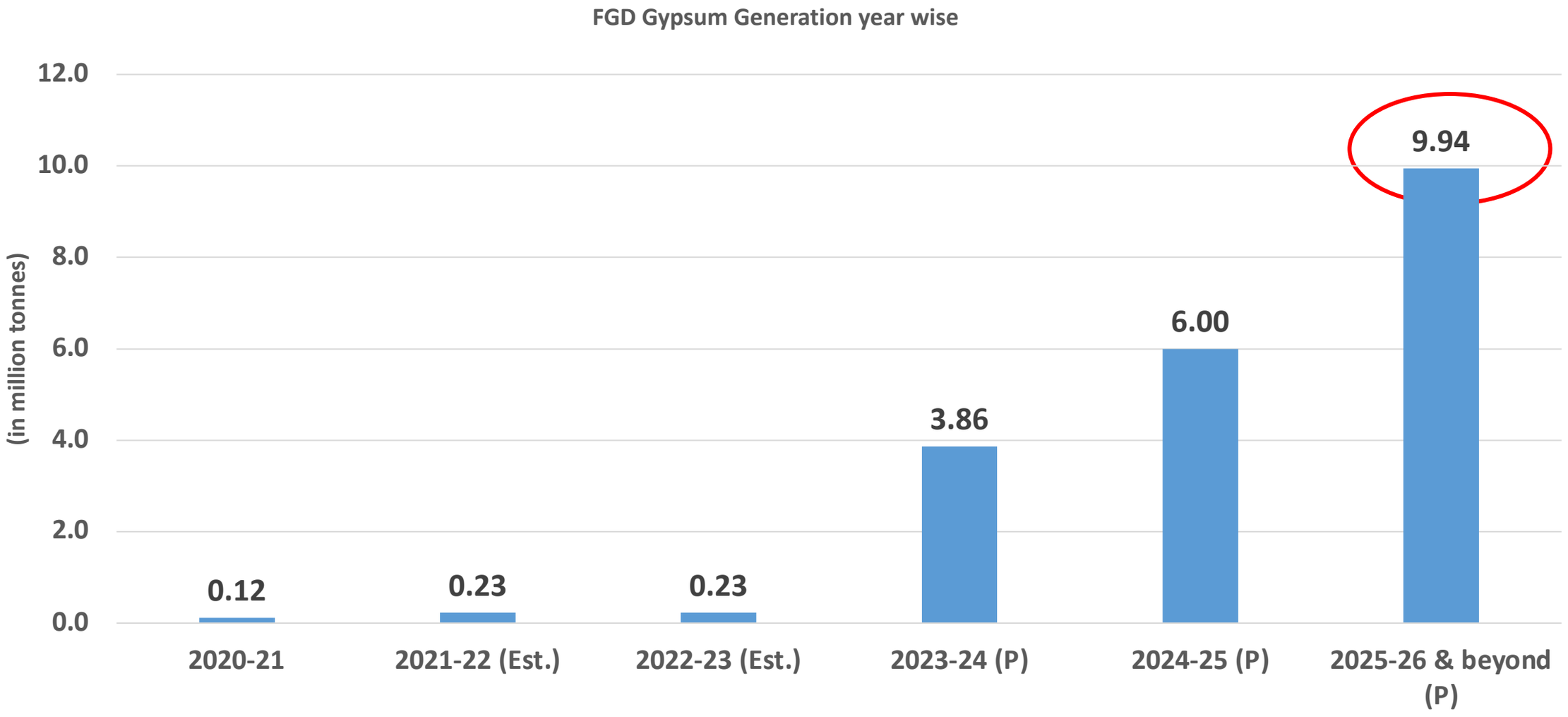
- Annual Generation in India: **~9.16 mtpa**
- Total Annual Consumption: **~5.04 mtpa**
- Legacy PG accumulated: **~74 million tonnes**

Legacy Phosphogypsum accumulated in India



Total Legacy stock of Phosphogypsum: ~74 million tonnes

Projected FGD gypsum generation in India



Presently, FGD system installed in only 6 thermal power plants

Source: CEA, Ministry of Power, @ PLF 55%

Transportation of Gypsum from Paradeep to Gujarat via Sea Route covering a distance of ~4100 km

Despatch of Gypsum of IFFCO & PPL from Paradeep Port on 16 April 2023

Receipt of Gypsum at Jetty on Gujarat Coast of UltraTech Cement on 26 April 2023

Alternative Raw Materials (ARM)

Waste with mineral fraction contributing to clinker production higher than 50% and oxide constituents (C+Si+A+F+S) more than 80%

Waste/by-product	MTPA	Characteristics	Intended application
Fly ash (TPP)	270.00	SiO_2: 40-60%, Al_2O_3: 15-25%	3-4% as raw material,
Steel slag **Iron & steel industry**	27 (by 2030)	CaO: 45-50%, CaO_f: 2-6%	7% as raw material
Copper slag **Copper extraction**	2.0	SiO_2: 25.84, CuO: 1.20% Fe_2O_3: 68.29%	2% as raw material, added advantage as mineralizer
Pb-Zn slag **Zinc extraction by pyro-processing**	1.0	CaO: 15.20%, ZnO-12.3%, Fe_2O_3: 36.90%	Up to 6.0% as raw material, added advantage as mineralizer
Marble Slurry **Marble processing units**	5-6	Moisture: 25-35%, CaO: 15-40%, MgO: 2-17%	as raw material
Leather Sludge **Leather industry**	0.1	LOI: 40-55%, CaO: 20-30%, Al_2O_3: 5-8%	Up to 1.0% as raw materials

Alternative Raw Materials (ARM)

Waste/by-product	MTPA	Characteristics	Intended application
Jarosite **Zn extraction by hydro-metallurgical process**	1.0	Fe_2O_3: 36.42%, ZnO-3.0%, SO_3-31.05%	1.0-1.75% as raw material, added advantage as mineralizer
Barium sludge **Chemical industry**		BaO-37.48%, SiO_2-17.19%	2-3% as raw material
Red mud **Aluminum industry**	9.0	Fe_2O_3-39.11%, SiO_2-16.55% Al_2O_3-18.0%, Na_2O-5.45%	5-6% as raw material
SPL waste **Aluminum industry**		CaO-6.35%, Al_2O_3-22.92% F-9.45%	Up to 3.0% raw material, add advantage as mineralizer
E-catalytic waste **Petroleum refinery**		SiO_2-56.25%, Al_2O_3-27.41%	Upto 5.0% As raw material
Aluminum wastes **Aluminum industry**	0.6	Al_2O_3-45-65%, MgO-7-9% SiO_2-10-15%	1% used as raw material
By-product sand **Clay beneficiation**	3.5	SiO_2-91-92%, Al_2O_3-3-4%	5-6% as raw material

Alternate Raw Materials

Type of waste/by-products	Generation	Characteristics	Intended application
Ferro Chrome Slag **Ferrochrome alloy industry**	1.0	SiO_2: 25-30%, Al_2O_3:30-35% MgO:19-20%	Concrete aggregate
Lime sludge **Paper, carbide, sugar industry**	6.0	Moisture:30-50%, CaO:48-53%, SiO_2:2-8%	As raw material, masonry cement
By-product sand **During clay beneficiation**	3.5	SiO_2: 90-92%, Al_2O_3:3-4%	As raw material
Phosphochalk **Fertilizer industry**	74	CaO:45-48%, SO_3:5-9%, LOI: 340-38%	Masonry cement, bricks
By-product from soda ash industry	300 TPD	CaO:42-52%	As raw material
Kimberlite **Diamond mining waste**	1.0	SiO_2:35-40%, Fe_2O_3:10-12%	-
By-product slag **Gasification of pet coke**	-	SiO_2:40-42%, CaO:18-20%, Al_2O_3:20-21%	As raw material, as PI

Potential Alternate Raw Materials

Type of waste/by-products	Characteristics	Intended application
Carbide sludge	LOI:25-30%, CaO:60-70%, moisture: 50-60%	As raw material
Chromium sludge	CaO:35-40%, moisture: 35-45%, chromium: 8-10%	-
Phosphorous furnace slag	SiO_2:40-42%, CaO:46-48%	As raw material
Paper sludge **Pulp and paper industry**	CaO:45-50%, SiO_2:4-6%, LOI:35-40%	As raw material
EAF slag **Iron industry& steel**	CaO:52-54%, SiO_2:28-30%	As raw material
Construction & Demolition waste (C&D waste)	-	As raw material

Study on Use of Uranium Tailing Waste

- Uranium mill tailings are a radioactive waste product that's created when uranium ore is mined and processed
- In India, huge stock of uranium tailing waste are there.
- NCB has undertaken a study from BARC and UCIL on exploration of utilizing Uranium tailing waste in cement manufacture

Sustainability of Indian Cement Industry

- The present life of limestone mines is only 30 - 40 years.
- NCB has carried out study on “Standardization of High Magnesia (MgO) Clinker for the Manufacture of PPC and PSC”, produced using low grade High-MgO containing limestone
- The report has already been submitted to BIS for standard formulation
- The Standardization by BIS will enhance the life of limestone mines further by **15 years**.

Development of Portland Dolomite Cement

- NCB undertaken Investigation on development of PDC using high MgO limestone and dolomitic grade limestone from different geographical regions

- NCB Study recommended:
  - High MgO limestone/dolomite recommended as PI and
  - upto 25% as mineral additives for manufacture of PDC (durability studies underway)

BIS approved materials as Performance Improvers

S.No	Material	Name of Industries	BIS limit
1	Fly ash, TPP	Thermal power plant	<5%
2	Granulated slag	Iron & Steel Industry	<5%
3	Steel slag		<5%
4	Copper slag	Copper Industry	<5%
5	Pb-Zn slag	Zinc Industry	<5%
6	Metakaolin	-	<5%
7	Silica fume	Ferro silican alloy industry	<5%
8	Limestone	-	<5%
9	Rice husk ash	Agro waste	<5%
10	Spent fluidized catalytic cracking equilibrium catalyst (FCC E Cat)	Petroleum Industry	<5%

C&D Waste

- RCA: Recycled concrete aggregate. (From demolition waste of concrete)
- RA: Recycled aggregate (Predominantly from demolition waste including concrete, masonry and asphalt)

Recycled Aggregate

Recycled Concrete Aggregate

C&D Waste Composition

This category of waste is complex due to the different types of building materials being used, but in general may comprise the following materials :

- Cement Concrete
- Bricks
- Cement plaster
- Steel (from R.C.C, door / window frames, roofing supports, railings of staircase etc)
- Stone (marble, granite, sand stone)

Extent of C&D Waste Utilization in IS:383-2016

- ***Recycled Concrete Aggregate (RCA)***
  - ✓IS: 383-2016 permits its usage up to 25% for plain concrete.
  - ✓IS: 383-2016 permits its usage up to 20% for reinforced concrete for concrete grade of M25 and below.
- ***Recycled Aggregate (RA),***
  - ✓IS: 383-2016 permits its usage up to 100% in lean concrete (for concrete grade of M15 and below).

Waste Utilization in Construction Industry

NCB has done extensive research on utilization of:

- Industrial waste as an alternative to natural fine/coarse aggregates such as:
  - Iron slag
  - Copper slag
  - Bottom ash
  - Ferrochrome slag
- Sintered flyash as coarse aggregates in structural light weight concrete
- Construction & Demolition waste generated from old buildings, roads, bridges
- Development of guidelines and formulation of Indian Standard for use of cementless concrete (Geo-polymer Concrete)

BF Slag and Steel Slag as Aggregate in Concrete (as per IS:383-2016)

Type of Aggregate	Plain Concrete Percent	Reinforced Concrete Percent	Lean Concrete Percent(< M15 Grade)
BF slag coarse aggregate	50	25	100
Steel (LD) slag coarse aggregate	25	NIL	100
BF slag fine aggregate	50	25	100
Steel (LD) slag fine aggregate	25	NIL	100

Way Forward

- Circular Economy is directly linked to Decarbonization efforts and Sustainability of Cement Industry
- Blended Cements like Fly Ash based PPC and slag based PSC are the major contributors in reduction of carbon footprint of cement in India
- Further study to enhance utilization of wastes/by-products required without impacting the properties of cement/concrete
- Going forward, these materials will not be available as these are available presently.
- Identify collaborative research opportunities to identify areas where different quantity and quality of slags can be used
- Anchor a mission mode approach with all stakeholders to find out optimal use of opportunities for steel slag in Indian infrastructure sectors

Thank You For Your Kind Attention