

How to drive the Sustainable/Low & Zero-Carbon Construction, for Indian cement/concrete industries

¹Sasanka Sekhar Dey

¹General Manager, Head QA/QC

¹Concrete Technologist (CCTI, RMCMA)

¹JP AUTOCLAVERS & CO.

sasankadey.sekhar@gmail.com

Abstract—For the construction works & urbanisation, concrete is the main backbone of the modern society since last 3 decades, so the cement consumption (per capita cement consumption current status is 290 kg in India, below the global avg. value of 540 kg) is growing day by day, due to this concrete is the 2nd most consumed materials applicable for in all sectors, by man-made after the water in our earth. For these, the vast increasing the percentage of carbon footprints via. CO₂ emissions from the large production of the concrete which also lead to temp. increasing into the environment & tends to climatic change, which lead to increase the GWP (Global warming potential). **Clinker substitutions, application of SCMs, performance-based specifications, CCUS, re-circular economy & renewal energy integration** are the most successful decarbonisation/low & zero carbon construction levers for all massive carbon emission countries, to **control the global temp. rise not > 1.5-degree C.**

Apart from these, the negative effects of OPC/clinkers, we can replace it by the application of **SCMs to driving the concrete decarbonisation or reduce around 20%** (rough estimation) **of total CO₂ emissions according to Net Zero Carbon Roadmap for Cement & Concrete, as per GCCA.**

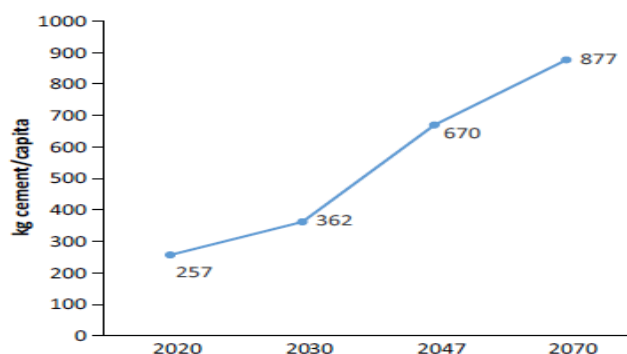


Figure 25: Envisaged trend in per capita cement consumption

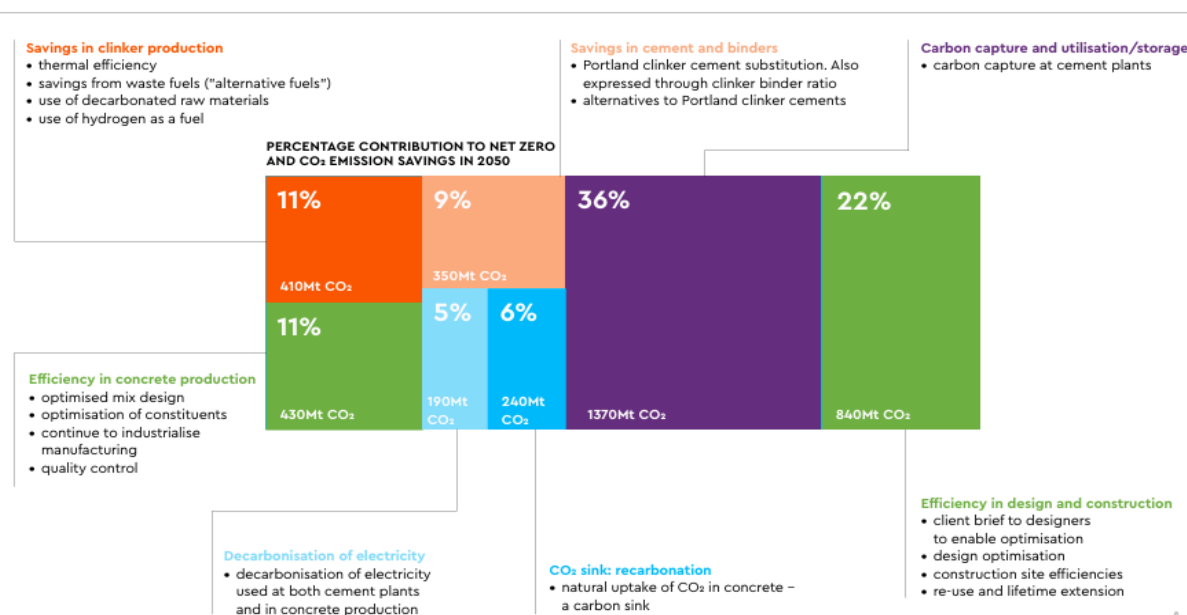
As per recent data, it has been observed that, total CO₂ emission across the world, 08% contribution done by all types of concreting works, specially from the concrete production by OPC, like **1 MT** of OPC Cement can produce equivalent to (including from production, transportation, and application for quantum of usages) **980 kg eq. of CO₂ emissions**, similarly **1 m³** concrete can produce around **600 kg of CO₂ eq.** Due to these, cement industry should change their course to reduce the CO₂ emissions effects by application of reducing the percentage of clinker (main responsible to carbon footprints or CO₂ emissions), replace by SCMs (supplementary cementitious materials) and make new types of cement/binder like PLC (Portland lime stone cement), LC3-50 (limestone calcined clay cement with 50% clinker), Composite cement etc (ternary blending with OPC/clinker along with Fly ash & GGBFS), which will acts as low carbon binders.

I. What are the steps to achieve the net zero commitment/decarbonation from the cement & concrete?

For enhancing the full **decarbonation/Net Zero CO2 emissions** for the both cement & concrete production, not only the application of SCMs is just enough, additionally we need to takes/adopts the following steps as listed below-

1. Awareness of carbon footprints or CO2 emissions form the both cement & concrete, its effects into the environment, increase the GWP/ temp. rise which directly impacts of climatic drastic changes, for this we need to estimating the carbon footprints/CO2 emissions value for the existing concrete practices.
2. Mind set-up to do this, by reducing the usage of clinker/OPC & increase the application of the SCMs.
3. Set a goal to limit the % of CO2 emissions reduce/net zero, effective from the certain period through interim & final target values.
4. Development of the codes & policies to reduce the carbon footprints & CO2 emissions & applications of low carbon binders & locally available SCMs/CRMs/Extenders to cut down the OPC content, which helps to reduce the CO2 emission by around 20%.
5. Different techniques used to reduce or capture the CO2 or **CCUS (Carbon capture, utilization & storage)** is one of the most important parts of the decarbonation techniques, which helps to reduce the CO2 emission by around 36%.
6. Implementation at field to ensure the same, by optimizing both efficiency in structural designs & concrete mix proportions (to reduce the void content by increasing the PD & least/optimized PV), which will help to reduce the CO2 emission by around 33%.
7. Implementation on decarbonation of electricity around 0.5% & CO2 sink for re-carbonation around 0.6% reduce the CO2 emissions.

ACTIONS TO A NET ZERO FUTURE



7 sectors/decarbonisation levers required to achieve the Net Zero carbon emissions by 2050, as per published by GCCA



II. Sustainable and low/zero-carbon construction

focuses on reducing embodied carbon in materials, minimizing operational emissions, and integrating renewable energy and circular practices into the built environment. It is both a technological and policy-driven transformation, with global net-zero targets pushing the industry toward innovation and accountability.

Here's a structured overview of current trends and strategies in sustainable construction: -

The main Key Strategies for Low- & Zero-Carbon Construction-

- **Low-Carbon Materials**
 - LC3-50 (Limestone Calcined Clay Cement): Reduces CO₂ emissions by up to 40% compared to OPC, clinker content 50% only.
 - C&D Waste Reuse: The use of construction and demolition waste in new builds, specially for recycled concrete fines (RCF) can be used as an alternative of both binders & fine agg.
 - Fly ash, GGBFS, and natural pozzolans (calcined clay): Widely used SCMs that reduce clinker demand & substitute the OPC & gain sustainability through their impacts on environmental, economical & societal.
- **Design & Standards**
 - Implementation of **net-zero construction roadmaps** with clear checkpoints (e.g., 2026 global roadmap).
 - Compliance with **green building certifications** (LEED, BREEAM, IGBC).
 - Emphasis on **life cycle assessment (LCA)** to measure embodied and operational carbon.
- **Renewable Integration**
 - Solar PV and thermal systems: Common in net-zero buildings across India.
 - Rainwater harvesting and greywater recycling: Reduce water-related energy loads.
- **Circular Economy Approaches**
 - Design for disassembly: Enables reuse and recycling of components, recycled concrete agg. (RCA), RCF can enhance the re-circular economy & gain sustainability.
 - Material passports: Track lifecycle and carbon footprint of building elements.

III. Standards & Roadmaps

For low & zero carbon construction the following standards/guidelines should be implemented pre & during works-

1. ACI 323-2024- How to achieve the Low carbon concrete
2. GCCA- Net Zero Carbon road map along with future actions to achieve the same in across the world, by 2050.
3. GCCA-India (TERI) guideline with reports to achieve the net zero carbon emissions in India, by 2070.
4. NRMCA- publications-Top 10 Ways to Reduce Concrete's Carbon Footprint & Guide to Specifications for Reducing Embodied Carbon.

Now talk about the two most important factors to achieve the title of the article- one is clinker substitutions & second one is the applications of SCMs; both are very much required to be part of the decarbonisation journey for Indian cement/concrete industries.

A. Clinker substitutions- is one of the most effective and immediately scalable levers for decarbonising cement production, directly targeting the industry's largest source of CO₂ emissions.

IV. Why Clinker substitutions required highly

In the concrete (mixed of Cement, Sand & Aggregates) cement contribution is generally in the range of (15-26) % bwoc. (for M30-M80), but 95% of carbon emission is responsible for the cement (main clinker) only. For this, to get lower side carbon emission by major replacement of OPC through the application of reactive SCMs or ultrafine SCMs or maintaining the **effective low clinker to binder ratio (0.50 to 0.58)** to keep the target concrete mix to achieve the desired performance as per the required design stipulations against the precise exposure conditions & significantly achieve the low carbon cement/concrete as per GCCA guidelines, below link shared in reference.

Clinker substitutions through the **Performance based specifications** is also the most import **decarbonisation levers/policies** to achieve the net zero carbon/CO₂ emissions from both cement & concrete by 2050 according to GGCA globally & by 2070 according to (GCCA-TERI) India.

On average globally, the **clinker binder factor is currently 0.63**. It is projected to reduce to 0.58 and 0.52 by 2030 and 2050 respectively. Regional and even country variations are inevitable due to differing material availability and market requirements.

Link-

<https://gccassociation.org/concretefuture/getting-to-net-zero/>

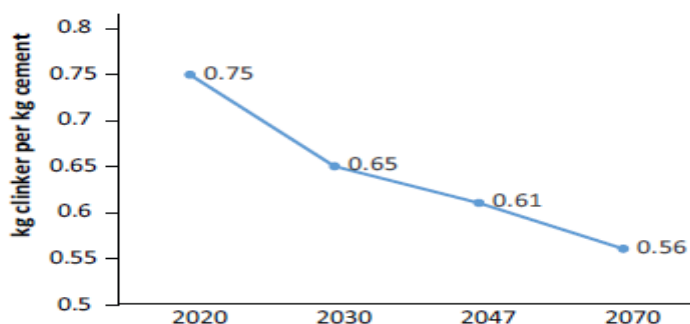


Figure 19: Projected trend in overall clinker factor

Clinker to binder ratio for all types of cement categories as listed above & noticed that, for OPC it is 0.92 to 0.98, while the application of LC3(50/60) it is in the range of (0.50 to 0.60), source- open source.

But due to limitation of clinker substitutions, India's current **clinker to binder ratio is approximately 0.72**, notably higher than the global average of 0.63 reported by the GCCA.

According to India's official decarbonisation roadmap for the cement sector, the clinker to binder ratio is currently **0.72 and is targeted to reduce to 0.65 by 2030, 0.61 by 2047, and 0.56 by 2070**.

India vs. Global Clinker to Binder Ratio-

- Global average (2023–2025): 0.63 This reflects increasing adoption of SCMs (Supplementary Cementitious Materials) like fly ash, slag, and calcined clays globally.
- India’s current ratio: 0.72 (>0.63) This figure is based on recent industry estimates and GCCA’s regional assessments. It indicates that India still relies heavily on clinker, although SCM usage is growing, especially in blended cements like composite cement, PPC and PSC.

Why India’s Ratio Is Higher-

- SCMs availability varies regionally: While India has abundant fly ash and slag, their quality (inconsistency) and logistics limit full-scale clinker substitution.
- Standardization and codes: Indian standards (e.g., IS 1489 for PPC, IS 455 for PSC, IS 16415- for composite cement) permit SCMs use, but uptake is uneven across regions and project types.
- Market preferences: OPC (Ordinary Portland Cement) still dominates in many structural applications, especially in the private sector and small-scale construction, especially for client’s opinions.
- Policies and awareness gaps: Unlike Europe or North America, India’s policy framework for low-clinker binders are still evolving.
- More usages of prescriptive based specifications (traditional system) to produce concrete mix design, significantly increase the value of clinker-binder ratio. To avoid this, adoption of performance-based specifications will be more one of the most beneficial tools against this.

Type of Cement	Additions	Replacement %	Clinker Binder ratio	GWP* (Kg CO ₂ e/T)
Portland Cement	Limestone	0 – 5%	0.9 - 0.95	950 - 915
Portland Limestone cement	Limestone	6 – 15%	0.89 – 0.80	880 - 750
Portland Pozzolana cement	Fly ash	6 - 35%	0.89 – 0.60	870 - 610
Portland Slag cement	Blast furnace slag	20 – 35%	0.75 – 0.60	740 - 620
Super sulfated Cement	Blast furnace slag	36 – 80%	0.59 – 0.15	610 - 230
Siliceous Fly ash cement	Fly ash	36 – 55%	0.59 – 0.40	590 - 420
Limestone Calcined Clay Cement (LC3)	Limestone + Calcined Clay	(15%+30%)	0.5	570 - 550
Composite Cement	Fly ash (15-35%) + Blast furnace slag (20-50%)	35% - 65%	0.60 – 0.30	600 - 360

Source- Open

A. The application of Mineral additives/SCMs—better known as Supplementary Cementitious Materials (SCMs)—are at the heart of concrete’s decarbonisation journey. They are not just pozzolanic/filler materials; they are strategic tools for slashing emissions, boosting durability, and unlocking circular economy benefits.

So, **SCMs (Supplementary Cementitious Materials) drive sustainability and low/zero-carbon construction by reducing clinker use, lowering embodied CO₂, enhancing durability, and supporting circular economy practices.** They are central to decarbonising cement and concrete, which together account for ~8% of global CO₂ emissions.

V. How to SCMs Matters/Mechanisms Driving for Decarbonisation for cement & concrete?

- **Clinker Reduction:** Traditional Portland cement production is carbon-intensive due to the calcination of limestone and high-temperature kiln operations. SCMs replace part of the clinker, directly lowering CO₂ emissions, through **clinker to cement ratio (CCR)**.
- **Waste Valorisation:** Many SCMs are industrial by-products (e.g. fly ash, blast furnace slag, silica fume), diverting waste from landfills and reducing the need for virgin raw materials.
- **Lower Embodied Energy:** Most SCMs require significantly less processing energy compared to clinker, making them inherently more sustainable.
- **Carbon sequestration potential:** Some emerging SCMs (e.g., carbonated industrial by-products) can embedded CO₂ during processing.
- **Extended durability:** SCMs often enhance resistance to chloride ingress, sulphate attack, and alkali-silica reaction—reducing lifecycle emissions by extending service life.

VI. Comparative Impact of SCMs on sustainability & carbon reduction through replacement of OPC

VII.

SCM Type	Source Material	CO ₂ Reduction Potential	Key Benefits
Fly Ash	Coal power by-product	25–35%	Workability, durability, reduced heat of hydration
GGBFS (Slag)	Steel industry waste	30–50%	Chloride resistance, marine durability
Silica Fume	Silicon industry dust	10–15%	High strength, reduced permeability
Calcined Clay	Kaolinite clays	25–40%	Widely available, good reactivity

SCM Type	Source Material	CO ₂ Reduction Potential	Key Benefits
Rice Husk Ash	Agricultural residue	10–20%	Circular economy, lightweight concretes

VIII. What are the best Net Zero/low carbon Construction Practices best fitted for India

- Sustainable Materials-** Smart construction materials, also known as intelligent, adaptive, or responsive materials—are engineered to sense, react, and adapt to changes in their environment without external control.
 - Shifting from prescriptive to performance-based spec.-** As the construction industry is keen to transition/shifting towards performance-based specifications, it is important to ascertain the ‘true performance’ in the scale of concrete and develop limiting values for specifications that are scientifically sound to ensure to achieve the desired performance.
 - Renewal energy Integration-** Integrating renewable energy into sustainable, low- and zero-carbon construction is essential for reducing operational emissions, achieving energy independence, and meeting climate targets. Solar, wind, geothermal, and biomass systems are increasingly embedded into building design and infrastructure.
 - The application of CCUS-** to capture the CO₂ during process of clinker & utilize for industrial usage & stored for millennium years to prevent entry into atmospheric zone, 5 processes are followed to achieve this, post combustion, oxy-fuel technique, direct separation, calcium looping & adsorption or reacting CO₂ with minerals by metal organic framework.
 - Application of SCMS-** main target to cut down the OPC/clinker content, which is majorly responsible for CO₂ emissions from both cement & concrete & make the concrete most economical in terms of low cost of SCMs, as compared to Portland cement.
- [1] **Re-Circular Economy-** Re-circular Economy & the application of recycled concrete aggregates or re-used concrete aggregates along with industrial wastage materials circulation to make use in diff. process.
- Clinker substitution-** by application of SCMs to reduce the clinker to binder ratio, like by LC3 cement it (clinker content) can bring down 50% from (90-95) % as per OPC & carbon emission reduction (40-50) %.
 - Smart Technologies:** Employing IoT and smart sensors for efficient energy usage and maintenance.
 - Lifecycle Assessment:** Conducting comprehensive assessments to evaluate the environmental impact of materials and designs over the building's lifetime.

IX. What are the best Net Zero/low carbon Construction Practices best fitted for India

In essence, sustainable, & low/zero-carbon construction is about rethinking materials, processes, and operations holistically—from clinker substitution to renewable-powered sites—so that the built environment becomes a driver of climate solutions rather than emissions.

Also, SCMs are the bridge between sustainability and performance: they cut embodied carbon, extend service life, and embed circular economy principles into construction

References

- [1] Global Cement & concrete Association- [Home : GCCA](#) & gccassociation.org/concretefuture/

Prepared By- Sasanka Sekhar Dey.

Concrete Technologist (CCTI, RMCMA).

General Manager, Head QA/QC.

JP AUTOCLAVERS & CO.

