Global Cement and Concrete Association

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GCCA Policy Document on Blended Cements and Supplementary Cementitious Materials

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October 2024

Contents

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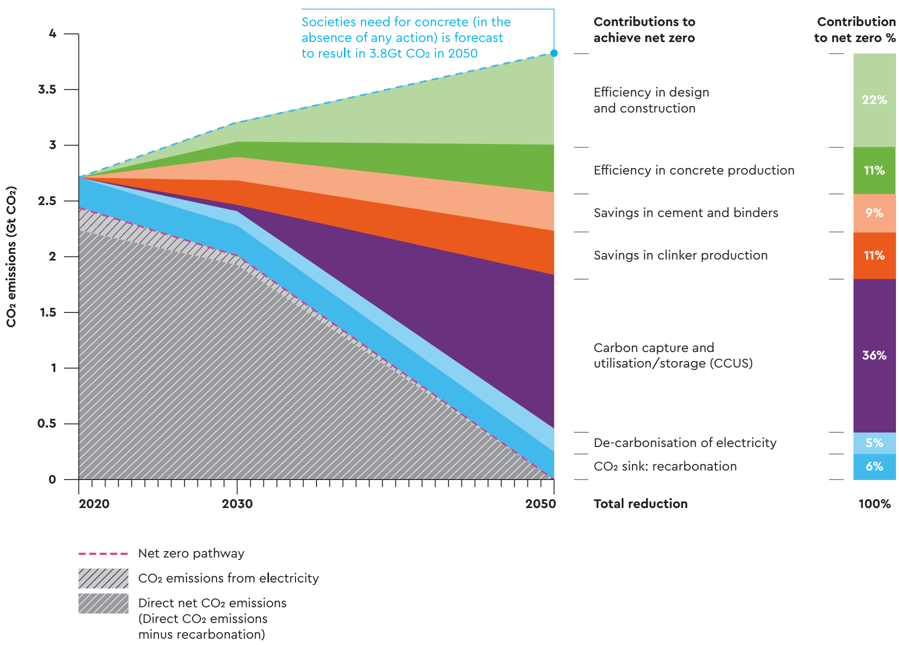

The Net Zero Pathway from the 'GCCA 2050 Cement and Concrete Industry Roadmap for Net Zero Concrete'[1]. An important decarbonisation lever is savings in clinker production. This policy document addresses how to maximise the potential CO_2 savings from this lever.

[1] Global Cement and Concrete Association. (2020) The GCCA 2050 Cement and Concrete Industry Roadmap for Net Zero Concrete. https://gccassociation.org/concrete future/wpcontentuploads/2022/10/ GCCA-Concrete-Future-Roadmap-Document-AW-2022.pdf

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1. Position Statement

GCCA Members recognise and promote the use of Supplementary Cementitious Materials (SCM) as a proven technology to reduce carbon footprint. To this end, SCMs play a key contribution to reach net zero carbon emissions by 2050 in the GCCA Concrete Future Global Roadmap and national cement and concrete Roadmaps. Many SCMs are by-products and wastes from other sectors, and hence their use also increases the circularity credentials of concrete[1].

The use of SCMs is not new in many regions. For example, in the U.S., SCMs were used over 100 years ago in concrete dam construction for overall cost and technical reasons (i.e. to lower heat of hydration). The long-term performance of the SCM concrete mixtures used is demonstrated by the performance of those early dam structures that are still in service today. In the current era, when decarbonisation is a priority there is a further reason for using SCMs in new structures.

In some countries, the use of SCMs on a project is already enabled through a framework of supportive policies, standards, regulations and specifications. In these cases, industry has been shown to respond with widespread availability of cement and concrete products that incorporate SCMs. To increase use of SCMs globally, the enabling framework must become more widely implemented and adopted. Over time, the framework must evolve and this will include updating standards and increasing the use of performance-based approaches where appropriate.

Supplementary Cementitious Material can be incorporated in blended cement and/or added at the concrete plant – and both of these should be recognised in the supportive framework with the appropriate requirements.

The GCCA and its members commit to:

1. **Research:** to increase the use of SCMs in cement and concrete products including evidence to amend standards and increase performance-based approaches.
2. **Standards Action:** actively engage and work with stakeholders in the value chain and especially standardisation bodies to achieve more flexibility in cement /concrete compositions whilst maintaining the essential characteristics of concrete, especially safety and durability.
3. **Supply:** Continue and widen supply of cements and concretes that use SCMs.
4. **Education:** Engage and provide supporting information, including through academic channels, to build stakeholder awareness and knowhow on blended cements and SCMs.
5. **Advocacy:** Advocating for government agencies to introduce low carbon / green procurement schemes that incentivise all decarbonization levers, including the use of blended cements and SCMs which is a proven lever in this regard.

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2. Glossary

Additions, Extenders, Substitutes, Secondary Cementitious Materials: See supplementary cementitious materials. The term supplementary cementitious material (SCM) will be used within this document.

Admixtures: are chemical compounds added during cement and/or concrete manufacture to improve their properties or their production processes. By improving cement and concrete performance, the admixtures help reduce their carbon footprint. Note that in the USA, admixtures (as defined here) that are used in cement, are referred to as processing or functional additions.

Binder (definition): A binder is a material that sets and hardens by chemical reaction with water (hydration). The hydration reaction results in the formation of a hard solid mass.

Binder (examples of materials): Binder means all material in concrete such as Portland cement, fly ash, ground granulated blast furnace slag (ggbs), natural pozzolans and other pozzolans that is permitted as cementitious material in the local jurisdiction. Cements that comprise two or more of these materials, such as slag cement (Portland cement and ggbs), Portland Limestone cement (Portland cement and ground limestone) and Portland Pozzolana Cement (Portland cement and pozzolana), are also referred to as binder.

Blended cement or composite cement: Blended or composite cements are made by blending or intergrinding Portland clinker with supplementary cementitious materials, such as pozzolana, ground granulated blast furnace slag (ggbs) and ground limestone.

Clinker: It is the intermediate product of manufacturing of Portland cement. It is a hydraulic material composed mostly of calcium silicates, and other phases containing aluminium and iron. Typically this is made in a rotary kiln at temperatures around 1450ºC by sintering a mixture of calcium, silica, alumina, and iron. These elements are traditionally attained from limestone, sand and clay. The use of waste materials containing these elements is becoming widely accepted within the industry. To produce cement the clinker is ground with calcium sulfate, and other constituents, known as supplementary cementitious materials and cement admixtures (or processing additions), as the manufacturer chooses.

Cement: Cement is a hydraulic binder, i.e., a powdery material that when mixed with water forms a paste that sets and hardens. It is produced by grinding clinker Portland with calcium sulfate and may contain different amounts of supplementary cementitious materials and cement admixtures (or processing additions). A "blended cement" contains an SCM. The cement mixed with water and sand forms mortar, and mixed with water, sand and coarse aggregate, forms concrete.

Clinker, cement ratio: The 'clinker-to-cement ratio' describes the amount of clinker in the cement.

Clinker:binder ratio: The 'clinker-to-binder ratio' describes the amount of clinker in the binder (or cementitious materials component) in the concrete or mortar.

Supplementary Cementitious Materials (SCMs): Supplementary cementitious materials are a wide range of both naturally occurring and industrial byproduct materials that are added in making a blended cement or added as constituents of concrete to reduce the CO_2 footprint and modify performance of cement and concrete. Some supplementary cementitious materials, like fly ash and ground granulated blast furnace slag (ggbs),

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are by-products and wastes of other industries, and their use in cement and concrete contributes to the circular economy. Other commonly used SCMs are ground limestone, natural pozzolans, calcined clay and other artificial pozzolans obtained by calcining natural materials. Recycled concrete fines can also be used as an SCM. Innovative processes and materials may result in new SCMs.

For further information: visit https://gccassociation.org/cement-and-concrete-innovation/clinker-substitutes/

3. Introduction

Concrete is the most used man-made material because of its inherent properties including durability, strength, wide availability, and relative ease of use. It is commonplace in many countries to use SCMs, often by-products from other industries (such as fly ash from coal fired power stations and ground granulated blast furnace slag (ggbs) from iron production), and natural materials, (such as pozzolans, ground limestone) and calcined clay as a portion of the blended cement that reduces the clinker to cement ratio, or as a portion of the cementitious materials in concrete to reduce its clinker-to-binder ratio. SCM percentage of the cementitious materials are dependent on available materials, their reactivity, local standards or project specifications, and the concrete performance required for different applications. In many countries typical percentage of SCMs in cementitious systems vary between 30% to 50% and for some applications can exceed 70%.

SCMs allow the production of a range of cements and concretes with reduced CO_2 footprint. For some applications, the properties of the concrete can be enhanced by SCMs, in appropriate amounts, in particular durability and hence service life, further contributing to the reduction of whole life carbon in construction.

SCMs can be incorporated in blended cement manufactured at the cement plant or added to mixtures at the concrete plant. The components that make up the cement and concrete have an impact on their properties, so standards and specifications state the type and proportion of SCMs that can be used to enhance performance or protect against any detrimental impacts. Standards are typically a combination of performance (for example strength) and prescriptive which stipulates, for example, the % of SCMs and/or cement content in concrete. Standards are developed and revised over time and reflect actual performance and commonly agreed experience. GCCA members are actively engaged in development of further performance-based content in standards.

4. Availability of SCMs

There are a wide range of Supplementary Cementitious Materials and their availability varies geographically and over time.

Fly ash and ggbs, are from coal fired power stations and iron blast furnaces respectively. In many locations, currently, the available supply of fly ash and ggbs exceeds the demand from cement and concrete producers. Both the energy and steel industries are globally undergoing changes leading to fly ash and ggbs becoming less available in many places in coming years, but in some major economies the absolute scale of fly ash and ggbs production is not decreasing (and in some regions is increasing) even in the medium term. For example, in India the research institute TERI[2] forecast that fly ash production of 281 and 256 million tonnes in 2030 and 2050 respectively. This is compared with 271 million tonnes production in 2020.

[2] Communication from The Energy and Resources Institute (TERI) in preparation for forthcoming India Roadmap for cement and concrete industry

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With regards ggbs, TERI forecasts this to increase from a 2020 value of 34 million tonnes to 67 and 116 million tonnes in 2030 and 2050 respectively. These values compare with a current use in India of fly ash and ggbs together of 93 Mt (Industry Data Analysis, TERI). Phasing out of coal fired power stations and blast furnaces will be quicker, even far quicker, in some developed economies, and these are often countries where available materials are being well utilised. It is of note that in these countries harvesting of stored/landfilled fly ash is increasing, to provide supplies that might no longer be available due to coal-fired power plants closing. In some cases, beneficiation or other technology is being implemented to make previously unsuitable materials suitable for construction applications. With respect to slags, future low carbon metal processes may produce new slags that are suitable for use as appropriate SCMs.

Limestone is increasingly used as an SCM in blended cement or added at the concrete plant. As an example, in the USA it can be used as an ingredient in a blended cement at a maximum percentage of 15% and uptake has increased rapidly in recent years (see Annex A1). In contrast, it has been used extensively for decades in Europe and Latin America. Furthermore, limestone cements are used at higher limestone levels for certain applications, and cutting-edge concrete technology is enabling the use of ever higher limestone percentages. Limestone is both widely available and at scale. In addition, given that it is the main input into cement kilns, it is also available as an SCM in convenient locations.

Natural pozzolans are not as widely available as limestone, but where they are available it is often at a scale that means they can play a significant contribution to decarbonising cement and concrete. For example, natural pozzolans are the most consumed SCM in Guatemala, Chile, Ecuador, the Dominican Republic and Peru, with above 20% in the first two cases.

Calcined clay is an SCM that is based on clays with specific chemistry. These are available at scale and whilst not everywhere they are widely distributed, particularly in tropical regions. Whereas calcination of limestone to make Portland cement clinker produces CO_2, the calcination of clay does not produce CO_2 unless the raw clay contains calcium carbonate. The calcination process of clay is at a lower temperature than that used for production of Portland cement clinker, therefore the CO_2 emissions from generating the heat in the kiln are less than for clinker. Therefore, whilst calcined clay has a higher CO_2 footprint than other SCMs, it can be used to make a cement/binder with lower CO_2 footprint than a Portland cement (which has no SCM). Recent developments have optimised combinations of calcined clays and ground limestone as SCMs, allowing a clinker reduction of up to 50% and maintaining a similar performance to existing cements[3].

5. Quality of SCMs, and products incorporating them.

Quality control (QC) and quality assurance (QA) practices have been established to ensure confidence in the characteristics and performance of SCMs themselves, blended cements that incorporate SCMs and concretes with SCMs mixed at the concrete plant. Underpinning these are robust standards that set out the requisite properties and test methods for SCMs, cements and concretes. For example, for SCMs, much of the world either uses ASTM or European based-standards.

[3] ECRA, The ECRA Technology Papers 2022

6. Standards and specifications for use of SCMs

There are well established standards, in some locations, for the use of most SCMs either in blended cements or as combinations with cements in the concrete plant. These include standards such as ASTM and EN that are used widely across many countries. However, there are still locations where SCM use is not optimised because of restrictive requirements in standards. These should be addressed through adoption of good practice from other standards. It is to be noted that, inclusion of more performance-based approaches that permit more flexibility compared with prescriptive standards can result in lower clinker binder ratio concretes. ASTM Committee C01, at the time of writing (June 2024), is close to publishing a new standard for performance evaluation for SCMs.

A performance-based approach to allow for well-tried and proven constituents to be used outside the ranges defined by existing standards, which are often partially prescriptive in nature, can be achieved by technical justification of necessary concrete properties within existing available test methods. A GCCA paper[4] outlines which properties should be tested to guarantee the performance depending on exposure conditions and application. It also provides examples of the appropriate test methods to be used.

Performance-based approaches should also be developed to allow the qualification of new, alternative cementitious materials. These will need to extend beyond usual performance testing to also encompass other aspects such as environmental impact leaching, H&S and durability. For new constituents, particularly those whose chemistry and mineralogy are different from the systems used today, test methods will have to be adjusted to reflect their short-, medium- and long-term performance.

In the medium term, complete freedom by "pure" performance approaches based on a limited set of verification parameters bears too many risks of misuse, misinterpretation and failures, which could jeopardise concrete as a safe and durable construction material.

Design and construction codes refer to material standards and may in isolated cases state material requirements. A barrier in some jurisdictions can be a lack of joined up approach across the material standards for cement, concrete and the design and construction standards, and this can sometimes be simply overcome by ensuring design and construction codes and standards refer to the most recent material standards.

Client requirements, typically referred to as project specifications, for concrete, both on publicly funded contracts and those used by private designers, should refer to the latest available standards and avoid, for example, requirements to only use Portland Cement (i.e. no SCMs) unless there is a strong technical justification. Where available in standards, performance-based approaches should be permitted in project specifications. The synergy between performance-based requirements and reduction of carbon footprint should be recognized by designers and owners. (For major government clients, their client requirements are sometimes referred to as "building codes" because they are applied across all government department projects at such a scale, it is akin to a code.)

Geographical variation in standards remains, despite globalisation and wide use of ASTM and EN documents. As a consequence, there is scope for transfer of good practice whilst still recognising good geographic reason for differences, such as climate. For example, Brazil has relevant /necessary test methods for performance for pozzolans to be used in cements and this good practice could be applied elsewhere.

[4] GCCA; GCCA pathway to more flexibility in standards: Performance Based Standards; 2024

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Calcined clays are worthy of note because they are currently not widely used but will play an important role in decarbonising the cement sector, and standards and specifications need to be in place to enable their use. The European, US, and Brazilian standards have permitted calcined clays in cements for decades, but only recently, for example, have the standards in the second biggest market of all, India, been updated. It is important that concrete and cement standards are aligned where circumstances allow, and this is not always the case. For example, whilst the EN concrete standards permit cements with calcined clay, local application rules can restrict their use in response to lack of local experience.

7. Role of Construction Clients, Contractors and Designers

Construction clients and their contractors/builders and design teams specify the construction works and materials. There are numerous examples where these specifications restrict or hinder the use of SCMs in applications where there is no reason why this should be the case. It happens because of custom, habit or lack of awareness of SCMs.

The public sector is typically the largest construction client, but with multiple tiers and agencies, acceptance of SCMs at the highest level may take years to deliver change on actual projects. In the USA, only recently in the last decade numerous State Departments of Transport have changed their requirements and now allow blended cements. This was despite neighbouring states permitting and successfully using blended cements in the same highway structures that passed through both states. Similar examples are true today across many countries both in public and private procurement.

The industry is committed to maximising the use of SCMs but to do so requires client support in specification requirements.

8. Specific Sustainability Benefits

The three major sustainability benefits of use of SCMs are decarbonisation, circularity and enhanced durability performance which leads to reduced whole life construction carbon.

Decarbonisation: SCMs can significantly lower the carbon footprint of cement and concrete. Environmental Product Declarations for cement and concrete products can be sourced to check the precise reductions in Global Warming Potential (GWP) achieved through use of SCMs in different locations.

To provide an indication of carbon footprint reductions compared with a concrete with no SCM:

- 30% fly ash concrete and 50% ggbs concrete have 27% and 42% lower carbon footprint[5]
- Portland-limestone cement (PLC) in the USA can contain 5% to 15% limestone and typically achieves a reduction of up to 10% on carbon footprint[6]
- Limestone calcined clay cement (LC3) has a clinker binder ratio of 50% and results in a 40% lower carbon footprint[7]

[5] MPA-The Concrete Centre, Specifying Sustainable Concrete, 2020

[6] PCA, 2024 Portland-Limestone Cement U.S. Fact Sheet,2024

[7] ACEEE, Adoption of Limestone Calcined Clay Cement and Concrete in the U.S. Market, 2024

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Circularity

Use of SCMs contributes to circularity. A key circular economy principle is use of unwanted materials from one sector to replace raw materials in another sector. SCMs such as fly ash and ggbs are unwanted materials from the electricity generation and steel sectors respectively and use of these materials by the cement sector reduces use of clinker and hence virgin raw materials. Similarly waste from the ceramic industry, rejected clay, can be suitable for calcined clay.

Durability

SCMs often result in enhanced durability of the final hardened concrete because of improved performance in addressing challenges such as sulfate resistance, reduced chloride ingress alkali silica reaction. These can be used by designers to deliver long lasting infrastructure with reduce maintenance requirements. This in turn delivers economic, environmental and social sustainability because of lower whole life costs, less frequent material replacement and reduced closures respectively.

9. Policy Recommendations: Enabling Policy Conditions

Use of blended cements and SCMs can be increased in the immediate term with governments and policy makers acting as follows:

1. Ensure necessary support for timely review, approval and publication of standards to ensure latest standards are available.
2. Ensure cement, concrete, design and construction codes and standards, and building regulations where applicable, are aligned and congruent. For example, construction codes must refer and default to latest available material standards.
3. Ensure Government and its agencies take the lead in public projects by specifying low carbon cements and concrete, through use of blended cements and SCMs, while taking into account the whole life carbon and performance of projects. We recommend major government agencies responsible for construction, are asked to review specifications to ensure they permit use of blended cements, SCMs and latest material standards.

Use of blended cements and SCMs can be increased in the immediate term with governments and policy makers acting as follows:

4. Promote formal construction and more industrialized uses of cement, understanding that this offers a better scenario to leverage a more efficient, safer, and optimized use of cement and SCMs in concrete production.
5. Provide policy measures that encourage, incentivise and train clients and specifiers to use low carbon cement and concrete, in construction projects, based on a whole life carbon and performance assessment. The use of blended cements and SCMs is a proven decarbonization lever in this regard and policy measures should seek to enable their maximum use.
6. Enable access and avoid barriers to sourcing SCMs both from overseas and domestically. Whilst taking into account the transport carbon impacts, no blanket prevention of importation should be introduced. Domestically, regulations should enable access to materials that are valuable for input into the cement/concrete value chain. Circularity benefits should be considered in this regard.

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7. Establish government funding programmes to support development of material standards that will widen and accelerate the use of SCMS and blended cement.
8. Establish government funding programmes for product development and innovation for new SCMs.
9. Establish government funding programmes for development and application of test methods to enable more performance-based approaches.

10. GCCA Commitments

GCCA and its members recognise the need for the industry to further implement, support and advocate for greater use of SCMs. GCCA and its members commit to:

1. **Research:** Research to increase the use of SCMs in cement and concrete products including evidence to amend standards and increase performance-based approaches.
2. **Standard Action:** actively engage and work with stakeholders in the value chain and especially standardisation bodies to achieve more flexibility in cement /concrete compositions whilst maintaining the essential characteristics of concrete, especially safety and durability.
3. **Supply:** Continue and widen supply of cements and concretes that use SCMs.
4. **Education:** Engage and provide supporting information, including through academic channels, to build stakeholder awareness and knowhow on blended cements and SCMs.
5. **Advocacy:** Advocating for government agencies to introduce low carbon / green procurement schemes that incentivise all decarbonization levers, including the use of blended cements and SCMs which is a proven lever in this regard.

Appendix A1: USA experience: Portland Limestone Cement and rapid adoption

Use of Portland-Limestone Cement (PLC) is now widespread in the USA, but this has only relatively recently been achieved. PLC was defined in national cement specifications in August of 2012. However, federal and local government agency standards and engineering and architectural model specifications did not include reference to PLCs (and often not to blended cements at all); in effect, this precluded the "new" (to the US) material from being considered on many construction projects. A programme of increasing awareness of PLCs and education across the construction industry was executed, and this was introduced while listening and responding to user feedback. Extensive effort was expended to introduce PLC in standards. Major users (like state DOTs) were targeted to gain acceptance, with initial focus on lower risk applications before extending to structural applications. Decades of research in the USA and elsewhere on PLCs was summarized and presented to specifying agencies, engineering agencies and other interested parties. Many laboratory studies and field test project installations were required to respond to concerns about local mix designs and local environments, reflecting a conservative attitude in the construction industry. After almost 10 years, use of PLC began to increase steadily and in mid-2023, PLC became the most common cement produced in the US. In 2023 alone, it is estimated that about 3.9 million metric tonnes of CO_2 savings resulted from the use of PLC replacing portland cement in US construction projects.

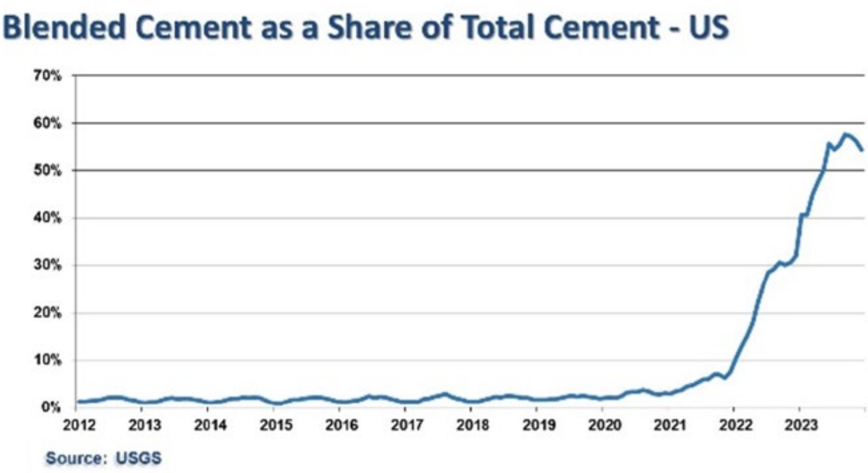

Figure A1: Growth in use of Portland Limestone cement in USA. Courtesy of USGS, Supplied by Portland Cement Association

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Appendix A2: Recent Europe experience with Cement Standards

The European Committee for Standardisation (CEN) recently published two cement standards that allow industry to produce new cement types outside of the scope of the long-established European cement standard EN197-1. The standard EN 197-5 allows for ternary cements with lower clinker contents to be produced, whereby two SCMs can be blended with clinker within certain ranges and criteria. EN 197-6 allows for a new SCM to be used in cement, in the form of recycled concrete fines. Both standards will allow industry to reduce clinker content in cement and concrete, whilst also improving circularity. The European Commission along with CEN are working to incorporate these new cement types as common cements in a future revision of EN 197-1.

Appendix A3: India initiatives

The share of blended cement production in total cement quantities manufactured in India was 30% in 1995, but it has increased to 73% of total cement production as of 2017.

To further increase the use of blended cements:

- In 2022 a report, "Blended Cement – Green, Durable and Sustainable" was developed by GCCA India in collaboration with NCCBM (National Council for Cement & Building Materials) in 2022. In this document, the advantages of different blended cements over OPC are discussed based on hydration, microstructure and permeability, rheology and workability, strength development, shrinkage (chemical, autogenous, drying, etc.) and cracks, leaching, alkali-aggregate reactivity, sulphate attack, reinforcement corrosion, long-term durability of construction, and usage in preparing high-strength concrete.
- In 2023 a key change in standards took place with the release of a standard on Limestone Calcined Clay Cement (LC3) – IS 18189:2023

With respect to enabling policies, in India it is mandatory to use fly ash in the construction of roads or flyover embankments within a radius of 300 km of thermal power plants. Over and above policy asks in the main part of this document, a specific policy ask by the India cement industry is a freight subsidy to allow the transportation of SCMs from surplus areas to cement clusters where SCM availability is limited.

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