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Trajnostna gradnja z betonom - 2. del: Nadaljnji potencial za optimizacijo

Sustainable construction with concrete – Part 2 – Further potential for optimisation

Nachhaltig Bauen mit Beton - Teil 2 - Weitere Optimierungswege

Construction durable avec du béton - Partie 2 - Potentiel d'optimisation supplémentaire

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Sustainable construction with concrete - Part 2 - Further potential for optimisation

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Nachhaltig Bauen mit Beton - Teil 2 - Weitere Optimierungswege

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EUROPEAN COMMITTEE FOR STANDARDIZATION
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European foreword

This document (CEN/TR 18290-2:2026) has been prepared by Technical Committee CEN/TC 104 “Concrete and related products”, the secretariat of which is held by Norway.

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Introduction

Currently, the boundary conditions for the erection and the operation of buildings and structures are changing. National and European laws and legislative procedures, such as the EU Taxonomy Ordinance and proposals from the Architects4Future initiative – require a restructuring of the construction industry with regard to climate change and climate change consequences as well as resource efficiency and a circular economy.

Besides these boundary conditions, increasing scarcity of raw materials, limited landfill space and the need to reduce GHG emissions are the global requirements that sustainable buildings, among others, demand a low consumption of raw materials and energy as well as the greatest possible flexibility of use and reusability or durability of the function in the building. Sustainable buildings have to meet environmental, economic and socio-cultural requirements, at the same time offer a high technical quality and have to be aligned to the processes of construction. Furthermore, ensuring user comfort and prioritizing health considerations are essential aspects of building design. The specific requirement profile of the client therefore determines the main points with which the numerous criteria of sustainability, such as for example in a certification, are anchored, are weighed against each other. All measures are based on the following key sustainability goals:

— An immediate and ambitious reduction in GHG emissions as a measure for climate protection,

— Take precautions for the already existing consequences of climate change,

— Resource conservation and material optimization.

When considering whether to preserve a structure or to dismantle it, the preservation approach has to always be followed in the interests of sustainability and the service life extended through appropriate maintenance.

This document is part 2 of two parts. Part 1 has the intention to give guidance, what measures can be taken in daily business already today to contribute to decarbonisation, resource efficiency and sustainability in the concrete sector. This Part 2 shows further measures and potentials to contribute to decarbonisation, resource efficiency and sustainability in the concrete sector in the medium and long term.

1 Scope

This document shows measures and potentials in the medium and long term to contribute to decarbonisation, resource efficiency and sustainability in the concrete sector compared to those measures that can already be taken in daily business today. Reduction of GHG emissions and resource efficiency are to be addressed at the same time and can affect each other; e.g. decreasing amount of fly ash in some countries due to the decommissioning of coal-fired power plants. As the embodied carbon in construction accounts for approx. 25-30 % of the GHG emissions of the life cycle of a typical building today, it has to be embedded into a LCA approach for the whole service life.

On CEN-Level as a consequence the general question is: “What can be done in the standards to go further in supporting decarbonisation, resource efficiency and sustainability in the concrete sector in the best possible way.

Case study — Case studies give examples (on a national level) for a deeper look

This symbol indicates required action

Values in the annexes are subject to change over time e.g. based on changes in the respective standards.

2 Normative references

There are no normative references in this document.

3 Terms and definitions

No terms and definitions are listed in this document.

ISO and IEC maintain terminology databases for use in standardization at the following addresses:

— ISO Online browsing platform: available at https://www.iso.org/obp/

— IEC Electropedia: available at https://www.electropedia.org/

4 Introduction

4.1 General

Construction is responsible for 36 % of GHG emissions and 40 % of energy consumption in the European Union – as the European Commission stated in the context of the so-called EU Taxonomy Regulation, see [1].

Emissions of CO_2 equivalents are attributable to the manufacture, construction, modernisation, use and operation of buildings, including upstream and downstream processes. In building construction, approx. 75 % of these emissions are due to use and operation. With engineering and infrastructure structures the amount of GHG emissions in the construction phase is somewhat higher.

Based on these figures, construction is increasingly the focus of political decisions and legislative procedures, such as the aforementioned EU Taxonomy Regulation [1] like e.g. the German Federal Climate Protection Act (https://www.gesetze-im-internet.de/englisch_ksg/index.html) or the French RE2020 (https://www.ecologie.gouv.fr/sites/default/files/guide_re2020.pdf).

Against this background three essential fields of action can be defined in concrete construction for the coming years:

1) By means of structural design measures, reduce the amount of concrete and reinforcement: as little as possible, as much as necessary.

2) The concrete used comes from decarbonised processes.

3) Use of concrete in the most resource efficient way (reduce wastage/wasting of materials by more optimized processes and concrete mix designs) including extension of service life and circular economy.

This triad has to be embedded in regulatory boundary conditions such as laws, regulations and standards [2]. This requires consistent action and can be supported by the following measures:

4.2 Regulatory measures

— Creation of functioning incentive systems for climate-optimized construction.

— Incentive for CO_2-efficiency by (public) procurement.

— Reversal in regulations: Sustainable building as a standard instead of – as before – as an exception.

— Establishing tools for the rapid implementation of improvements and innovations.

— Shortening approval procedures for new climate-optimized building materials and construction processes.

— Target setting in regulatory specifications is established on building/structural component level.

Case study	In France, the new regulation RE 2020 gives rules for decarbonising construction [9]. Levels (Benchmark) of GHG emissions during construction are given for individual houses, collective housing, offices and schools. Since 1st of January 2022 this regulation applies for housing, and since 1st of July 2022 for offices and schools. These levels will be reduced during the following years. For further details see Annex A.

4.3 Structural measures

— Digital planning techniques, such as BIM, and automated construction process chains.

— Innovative construction techniques, such as digital manufacturing and hybrid construction methods.

— Increased efficiency and reduction of wasting through e.g. lean construction and particularly material-saving, optimized load-bearing structures (e.g. prestressing or post-tensioning techniques and use of high-performance concretes).

— More precise durability calculations and new durability concepts and lifetime analyses.

4.4 Building material technology measures

— Use of low carbon or near zero materials, such as clinker efficient cements and climate friendly concretes.

— With the same performance and durability use of non-corroding reinforcements to reduce component geometry, increase service life or dispense with coatings.

— Use of reused/recycled/repurposed materials or components. Utilize the existing building stock as much as possible.

— Use of optimized concrete mix-designs in terms of carbon footprint, content of recycled materials and water consumption.

4.5 Construction process engineering measures

— New manufacturing methods

— Prefabrication of components

— Improved accuracy in construction

It is also foreseeable that the current building stock will have to be preserved, revitalized or upgraded much more often in the future and that maintenance will subsequently continue to gain in importance compared to the new building, see [3].

4.6 Examples for roadmaps on decarbonisation and resource efficiency

Roadmaps on decarbonisation and resource efficiency worldwide address the measures and levers to reach a decarbonised concrete sector by 2050 at the latest (e.g. [4, 5, 6, 7, 8, 9] including the OFICEMEN roadmap for the Spanish cement industry to 2050).

Even though methodologies are not 100 % comparable some conclusions can be drawn (see Figure 1):

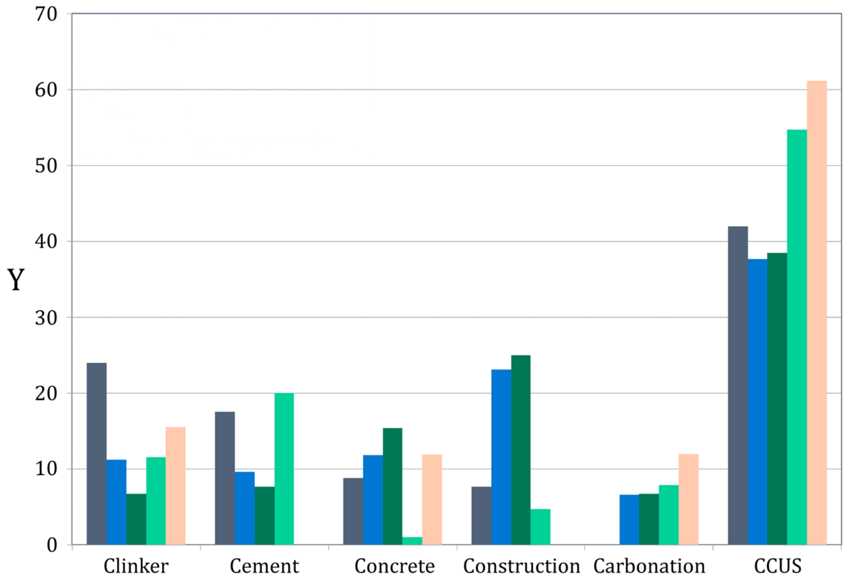
— Without Carbon capture and use (CCU) or Carbon capture and storage (CCS) decarbonization of cement and concrete will not be possible

— The potential to contribute to decarbonisation by low carbon cement and concrete is seen in a range between approx. 12-26 %

— The potential to contribute to decarbonisation by innovations in design and construction is seen in a range between approx. 5-25 %

— As a consequence, a range of 30-40 % reduction of CO_2 in the concrete sector is seen by existing roadmaps to be possible with the levers and measures that can be supported by standards prepared by CEN/TC 51, CEN/TC 104, CEN/TC 229, CEN/TC 250 and their sub-committees and working groups

— This CEN/TR gives guidance how CEN activities and committees dealing with cement and concrete support that these levers/potentials will be realized



Key

Y Percentage CO_2 reduction

CEMBUREAU

GCCA

Australia

Germany

Mineral Products Association

Figure 1 — Potential of CO_2 reduction as seen in several roadmaps on decarbonisation (examples)

It is foreseeable that by 2050, around 75 % of the concrete produced globally will be manufactured in regions with a stressed water situation. Water-reduced concrete mixes is used when possible and washing of aggregates before using them in concrete is avoided whenever possible [37].

In general, the following measures and levers have been addressed within the existing roadmaps (Table 1):

Table 1 — Examples of measures and levers that can support decarbonisation have been addressed within the existing roadmaps

Area	Measures and levers (Examples)
Design with a focus on low carbon technologies and material efficiency	— Prestressed hollow core slabs or voided slabs. — More differentiated selection of the concrete grade. — Assessment of the concrete strength, for example, after 56 days. — More industrialized process, for example, by a moderate shift from onsite work to precast. — Design for lifetime extension, repair and reuse. — Design for the limit state of carbon neutrality. — Use of high-performance concrete (CO_2 per cubic meter an MPa to compare to CO_2 at the building level).
Electrification of manufacturing process and transport	
Optimizing of the total binder volume (sum of cement and SCM) to reduce of GHG emissions	— Packing density optimization of concrete and optimization of aggregate grading. — Appropriate balance between performance/descriptive approach. — Lowering volumes of fresh concrete wastings (better forecasting of the demand and adapted truck size). — Dry mix vs. wet mix. — Tools to assess CO_2 performance and technical performance of concrete at the same time.
Further lowering the clinker factor in cement	Producing cements with higher content of SCMs, e.g.: — Limestone content of 20 per cent or more; — “LC3” –50 per cent clinker, 30 per cent calcined clay and 20 per cent limestone; — 35 per cent clinker, 45 per cent fly ash / calcined clay / GGBFS and 20 per cent limestone; — Standards and application rules which reflect the benefits of CO_2 efficient cements and enable their (differentiated) use in concrete; — Introducing these new cements in concrete standards.

To achieve an equivalent strength performance the reduction of clinker and/or supplementary cementitious content in a concrete mix goes frequently hand in hand with a reduced water content enabling water saving at the same time. Recently it has been shown, that with a water content of 130 kg/m^3, which constitutes a saving of about 20 %, a CO_2 reduced concrete with highest requirements in terms of pumpability and robustness against temperature variations can be realized even applying the prescriptive design concept [64].

5 Innovation in design and construction

5.1 Boundary conditions

The success of concrete construction in recent decades is in particular due to the fact that the starting materials are available almost everywhere in the world and can be obtained at comparatively manageable costs. In addition, the construction method is very robust: Deviations from the planning model do not automatically mean that the concrete components are not able to cope with the real conditions in addition to the longer durability without costly maintenance. However, this robustness is at the expense of the efficiency of the construction method – both in terms of material requirements and emission volumes. In this respect, this success of concrete construction is at least partly due to the preference for economic efficiency and robustness over climate and resource efficiency or sustainability laid down in building rules. Technologically, this requires at least partially avoidable emissions and partly also wasting of material resources.

For the construction industry and with that also for concrete construction, becoming “greener” no longer means improving in small steps by 2030 and then establishing a climate-neutral construction industry. Rather, all measures to be taken are aligned with the following goals/actions:

— With the same performance immediate and significant reduction of GHG emissions as a measure to limit climate change,

— adaptation of existing and new buildings to the already existing and expected consequences of climate change,

— resource conservation, extension of service life and effective circular economy.

Enormous improvements are necessary, which are accompanied by technical and economic changes. For the medium-term perspective, further optimizations have to be planned. In addition, sustainability and resilience strategies for the long-term perspective have to be developed and implemented as quickly as possible.

Designers and architects play a crucial role and will increasingly adopt aspects of resource efficiency and climate protection in their design and construction considerations. From the point of view of designers, architects and building owners, the selection and application of concrete (including the type of cement used) as well as the building structure, including its service life, are the main influencing factors. Structural optimization, as well as improved design assumptions and methods, are the tools to be used by designers. Contractors also can contribute to new and improved construction technologies. Both designers and contractors will increasingly emphasize issues such as lifetime extension, repair and reuse [5].

Innovation through design and construction focuses on [5]:

— Promoting design of building and infrastructure that includes a clear focus on material efficiency, specifying lower carbon concrete solutions and improved construction technologies.

— Ensuring structural optimization that allows for lifetime extension, repair and reuse.

— Use of high-performance concrete for an optimization of concrete volumes[1].

[1] It could be noted that as a first approach, the CO2 footprint varies as the square root of f_{ck}, for elements where the compressive strength is the critical factor for sizing, cross section reduction can induce environmental savings varying as $1/f_{ck}^{1/2}$.
High performance concretes are also preferred in the case of truss structures.

Horizontal elements in concrete buildings contribute most to the carbon footprint. To optimize is a challenging task because of conflicting interests like open space area, flexible use and material consumption driving carbon footprint. Considering conventionally reinforced concrete elements the material intensity increases significantly with span width [67] constituting a preference for smaller span width looking at a concrete structure carbon footprint. Concrete strength and density are further influencing factors with similar potential for improvement. While the application of lower density concrete provides especially saving potential in housing structures with a small number of floors, a higher concrete strength class enables carbon savings especially in multi-storey buildings. Therefore, in scenarios where the span width is fixed and a greater height is desired, such as in collective housing with post and beams in concrete, the utilization of higher strength concrete could be advantageous.

The choice of design and materials for a given building is made during a multi-criteria reflection that is confirmed by a set of calculations, with potentially back and forth between the different actors of the project taking into account the performance and durability. Minimizing the environmental impact of the structure is one of these criteria. It is from a global perspective that this impact is assessed, taking into account above all the performance, durability and functionality brought to the structure.

It is important to note that both design solutions and the choice of materials have influences on the building environmental impact,

5.2 Lean construction with concrete

5.2.1 Stocktaking

In the sense of a stocktaking the question can be raised whether the concrete sector currently is "wasting" resources and emitting unnecessary greenhouse gases. If the answer to this question to some extent is "yes", the next question is why and how can this be changed. The following text gives some examples of what types of "wasting" currently exist in concrete construction and how this "wasting" can be reduced.

The term "wasting" here does not mean any material that is left over but in terms of a wasting of resources.

Wasting of resources results e.g. from an inaccurate description of the needs by the customer, incomplete planning, inappropriate constructions and wasting of materials as well as insufficiently adapted production and execution methods. This wasting is also caused in particular by insufficient coordination of what is built, how it is built and how it will be used later. In this respect, the first and most important step on the way to sustainability is to optimize the use and durability of material, human and time resources, as a joint task of all those involved in the construction process. In other words, on aspect of "going green" means becoming more efficient and leaner – i.e. "lean" – and working better together.

Wasting of resources is currently generated in a number of areas that are addressed immediately, such as [12]:

— oversized components;

— unnecessarily high demands on the concrete or the component;

— comparatively high variance in the production of concrete and its constituents;

— sometimes unnecessarily high cement and clinker contents;

— often unnecessarily high compressive strengths in the component, e.g. due to disregarded strength increase;

— neglect of the time-consuming curing due to the immense pressure of deadlines for the entire project; and

— neglect of an appropriate, value-preserving maintenance/repair.

5.2.2 Examples for wastage of resources in concrete construction and measures to reduce

These forms of wasting can be assigned to the classic aspects that play a role in the design of lean processes, see Table 2.

Table 2 — Examples for wastage of resources in concrete construction and measures to reduce [12]

Type of wastage	Example	Countermeasure	Reference to standards and regulations	Remarks
Overproduction	Oversized components and unnecessarily high demands on the concrete or the component	Clarification of the actual needs in a requirement for planning	Relevant standards of concrete construction	Can require more detailed preliminary considerations and advice
Waiting	Retrospective quality control, including 28-day compressive strength	Changeover to predictive quality control with the aim of further limiting fluctuations in production	Regulatory not yet recorded, therefore approval process can be necessary	Evidence is required that procedures that are already being tested work regularly
Defects and non-utilized talent	Comparatively high variance in the production of concrete and its constituents and high safety factors due to variance	Development of incentive systems for more precise production, for example by the fact that these lead to a reduction of the partial safety factor, whereby a higher utilization of the building material is achieved	Regulatory not yet recorded, therefore approval process can be necessary	Creation of incentive systems for the entire value chain – in other words, an “all-win-situation” in which the concrete manufacturer who optimizes his production also benefits
Defects and non-utilized talent	Exceeding manufacturing and manufacturing tolerances as well as limit dimensions	Approval of the incentive system for more precise construction and the associated reduction of the partial safety factor with the aim of a higher capacity utilization of the component	Tolerance class 2 according to EN 13670	In Germany currently not provided for in terms of standardization
Non-utilized talent	Neglect of the time-consuming curing due to the immense pressure of deadlines for the entire project	Making curing visible as a technologically important measure that brings advantages in terms of climate protection	Transferring curing to the list of “special services” in contracts	Proposals for changes are submitted to the relevant committees on European and national level
Overproduction	Disregarded strength increase	Raising the testing age to 56 or 91 days (or even beyond)	In principle, it is possible to add “sustainability” as a technical requirement for increased testing age	Note the effects on the construction process and durability

Focus is made on the necessary coordination between all the actors: designer/contractor/producer.