Opportunities and challenges for a more sustainable concrete

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Abstract

Production and use of concrete accounts for a significant part of the global CO_2 emissions. Increasing awareness and upcoming regulations demand ready-mix producers to reduce environmental impact of their products while keeping process efficiency and concrete performance at high levels. Concrete admixtures are crucial to meet these demands in a cost efficient way. New concepts like X-SEED®, a suspension of CSH nano-seeds, enable superior early strength gain at high SCM usage rates. Other options to reduce overall energy footprint are technologies that enable high workability of concrete while still utilising easy-to-produce, low-fines mix-designs.
A recognized barrier to promote sustainable concrete is the access to reliable data on environmental impact of different mix designs. To help concrete producers to quantify sustainability properties of their concrete, new calculation tools based on the European Standard EN 15804 become more and more available. Such tools enable an environmental assessment under a life-cycle-approach (LCA) and provide data for the application to recognized building certification schemes (e.g. DGNB, BREEAM, HQE, and LEED).

Keywords

Sustainable construction, green concrete, life-cycle analysis, admixture innovation, carbon footprint, concrete performance, seeding technology

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1. Introduction

1.1. Environmental footprint of Concrete

With approx. 30% of global greenhouse gas emissions and 40% of the energy consumption (1) , the construction industry has a massive contribution to the global environmental impact of human activity (2) (3). While the largest share of greenhouse gas emissions associated to buildings is generated during the use phase, there are still considerable emissions occurring during manufacturing of construction products and materials and during construction. Cement represents the most important driver for the environmental impact, in particular with regard to carbon footprint and energy use. About 5% of the global greenhouse gas emissions are due to the very energy intensive clinker production, the core component of ordinary Portland cement (OPC) (4). This makes concrete, and particularly its key component cement one of the largest contributors to global warming within the manufacturing sector. Therefore, along with the improvement of construction, the choice of construction materials will gain more and more importance as the industry is striving to reduce greenhouse gas emission.

1.2. Increasing importance of ecologically sound construction

The society is more and more aware on the potential sustainability improvement that could be achieved in the construction sector, particularly in buildings. This is creating a certain pressure to building developers, but it is also creating an opportunity for innovation in all stages of the construction value chain, including engineers, architects, and material suppliers. Both private and public sectors are seeking different ways to improve sustainability in construction (5). This trend is supported by the increasing network of Green Building Councils worldwide and the growing acceptance for certification systems for sustainable construction. Aside of the technical and financial performance, sustainability is becoming an integral part of the evaluation criteria in the tender processes for new construction. Efforts to improve and quantify sustainability of the products and at all stages of the construction process are becoming a market necessity. It is even likely that this development could gradually change the competitive landscape of the construction industry. Efforts to improve and quantify sustainability in all steps and products used in construction are becoming a market necessity.

2. Levers for more sustainable concrete

Usage of concrete accounts for a significant part of the global CO_2 emissions and cement, its most relevant component, is the key to push for more sustainable solutions in concrete. Increasing awareness and upcoming regulations demand ready-mix producers to reduce environmental impact of their products while keeping process efficiency and concrete performance at high levels. Concrete admixtures are crucial to meet these demands in a cost efficient way (6).

Admixtures, especially high range water reducing admixtures, do contribute substantially to the improvement of sustainability properties of concrete. The main drivers achievable with the usage of admixtures were highlighted by the European Concrete Platform to be:

- Optimized mix design - reducing embodied carbon dioxide, water content and energy by enhancing the effectiveness of the cement component
- Increased fluidity - reduces vibration noise and energy requirements during placing
- Reduced permeability - increases the durable life of the concrete
- Reduced damage from harsh environments – including marine, freeze-thaw and sub-zero situations
- Improved quality - better finish and reduced service life

The main leverage of admixture towards sustainability of concrete is the reduction of cement content in concrete, and/or the switch from OPC (CEM I) to composite cements. The main limitation of further reduction of the clinker phase in cements and concrete is often the reduced early strength due to the lower reactivity of the used supplementary cementious material (SCM). This is especially true for ready mix concrete used in cold weather conditions. Concepts to improve the reactivity of SCMs are subject to intensive research efforts (7), however they are not in broader commercial usage. A technology brake through has been achieved with seeding technologies focusing on boosting the very early strength development of the remaining clinker phase. Via this mechanism new concepts like X-SEED®, a suspension of CSH nano-seeds, enable superior early strength gain at comparatively high SCM usage rates. Making reduced clinker factors at maintained or even improved concrete performance possible, this technology contributes tremendously to reduce the overall environmental fingerprint of concrete in use (8).

Further technologies aim at the reduction of the overall usage of fines in concrete. Smart Dynamic Concrete is a concept for a new generation of highly fluid concretes for day-to-day applications. It enables to produce economical and highly fluid concretes which are lean in powder but easy to produce and highly robust. Thanks to its self-compacting characteristics this concrete does not need to be vibrated, which means no noise and no health hazardous vibrations for the workers at jobsite. Installation costs are drastically reduced, and the environment profits from lower usage of energy and CO_2-intensive powder materials.

While there are reliable and economical viable solutions for more sustainable concrete available, producers and users of concrete do struggle to quantify and compare different approaches and give data as basis for sustainability driven decisions.

3. Certification systems for sustainability of concrete

A recognized barrier to promote sustainable concrete is the difficulty to access to reliable data on environmental impact of different mix designs. Sustainability evaluation heavily depends on the availability and comparability of data for all relevant criteria. The clear trend is to have an evaluation over a broad range of environmental indicators to avoid distortions that single-criteria ratings could cause. Focus on just one impact category, (e.g. recycled content, renewable content, absence of hazardous substances, carbon footprint), may even provide incentives for less sustainable solutions as one factor may be optimized to the disadvantage of several others. Therefore, single-criteria approaches can easily lead to unsustainable solutions and ”green washing” (9).

One of the weaknesses of current sustainable construction efforts is the absence of globally recognized standards on performance, measurement and evaluation. There are currently several sustainability schemes for buildings with different grades of acceptance in the European market.

LEED (US) (‘*Leadership in Energy and Environmental Design*’) is a system established in the US since 1993, but increasingly used in Europe as well. The LEED Green Building Rating Systems for various building types are developed in a consensus-based way among the members of the US Green Building Council (US GBC). They evaluate environmental performance from a whole building perspective over a building’s life cycle, providing a standard for what constitutes a green building in design, construction, and operation. The LEED systems are designed for rating new and existing commercial, institutional, and residential buildings. Each rating system is organized into 6 environmental categories: Sustainable Sites, Water Efficiency, Energy and Atmosphere, Materials and Resources, Indoor Environmental Quality and Innovation in Design. Regional bonus points acknowledge the importance of local conditions in determining environmental design and construction practices. The characteristic of LEED, compared to other certification systems, is that it is not based on a life-cycle analysis, but on the assessment of selected criteria.

BREEAM (UK) (*‘Building Research Establishment’s Environmental Assessment Method’)* is UK’s Environmental Assessment Method for Buildings, developed by BRE. The first versions of BREEAM were published in the early 1990's and high performance within BREEAM has been a UK government requirement for publicly funded buildings since 2000. BREEAM covers different aspects of the building's impact, including some social and economic criteria, although the main focus is on environmental aspects: Management, Health & Wellbeing, Energy, Transport, Water, Materials, Waste, Land Use & Ecology and Pollution.

DGNB (Germany): The German Sustainable Building Council (DGNB for “*Deutsche Gesellschaft für Nachhaltiges Bauen*”) addresses the three pillars of sustainability when certifying buildings. It corresponds to latest European standardization activities regarding sustainability of building products, buildings and constructions. The following criteria groups are assessed: Environmental Quality, Economic Quality, Socio-cultural and Functional Quality, Technical Quality, Quality of the Process (Management), Site Quality.
HQE (France): Product assessment in HQE (*Haute Qualite Environmentale*) is based on FDES, the French Environmental Product Declarations. This Platform for construction and sustainable development was established in 1996.
VERDE (Spain) is a new GBR established in Spain by the Spanish GBC. For including the impacts of construction products, it refers to Environmental Product Declarations (EPD), which are being established in Spain, as well as some specific criteria such as the property of being a reused, reusable or recycled material.
LEED Italy is a direct translation of the original LEED from the USA, but with references to standards being changed from US standards to Italian standards. Regarding products, materials developed for US LEED should be valid for LEED Italy in most cases.

4. Environmental Product Declaration (EPD)

As sustainability criteria can also be deployed to assess the performance in construction , data is becoming more and more valuable and new companies providing data sets are being established in the construction sector. A relatively new form of data provision in the construction sector is the Environmental Product Declaration (EPD). An environmental product declaration is a standardized (ISO 14025, EN 15804) calculation to communicate the environmental performance of a product or system. It provides data based on life cycle analysis of the components used and is applicable worldwide for all interested companies and organizations. EPDs include information about the environmental impacts associated with a product or service, such as raw material acquisition, energy use and efficiency, content of materials and chemical substances, emissions to air, soil and water and waste generation. It also includes product, production process and company information.
Concrete producers can use EPD reports to provide an overview on several aspects of the environmental performance of the concrete, making different criteria quantifiable. They can be used as unified basis for the creation of different sustainability reports within the locally relevant schemes. EPD data allows for the assessment of the environmental profile of concrete based on selected indicators, as Global Warming Potential (also known as “carbon footprint”), Primary Energy Demand, Acidification Potential etc.
With an externally verified Environmental Product Declaration concrete producers can answer the increasing demand by architects and planners to provide sustainability data in a uniform and internationally recognized format. The data can directly be used in sustainable building design tools, e.g. to carry out a building Life Cycle Assessment. There are several national systems based on EPDs like the German IBU declaration, the French FDES declaration, the UK BRE Environmental Profile declaration or the European ECO declaration.
There are tools available to calculate EPD data of concrete mix designs, like BASF`s ”Life Cycle Analyzer”. General calculations can be performed based on recognized European data, however an individual analysis needs to be based on individual data for the specific concrete raw materials, where available. Such life cycle analyses can be done “cradle-to-gate” (concrete production only) or “cradle-to-grave” (considering the whole building life cycle). It gives data on the environmental and cost impact of different concrete mix-designs, allowing direct comparison of different scenarios. Such tools provide the basis for a concrete Environmental Product Declarations (EPD), giving input for most recognized building certification schemes (DGNB, BREEAM, LEED).

5. Conclusion

Concrete producers do have the chance to improve sustainability and performance of their product by mix design optimization and the employment of advanced admixture technologies.

To turn this chance into a business opportunity and finally into a market reality, concrete performance and sustainability properties need to be quantifiable and comparable. Concrete Environmental Product Declarations (EPD) provide transparency on the sustainability properties of concrete and give input for most recognized building certification schemes (DGNB, BREEAM, LEED). A stringent use of such data and application of standard methodologies will help to build and construct in a more sustainable manner, leading to more value for end users and the society in general.

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