Science around us

Innovations from BASF illustratively explained

BASF
The Chemical Company

From nanocrystals to concrete components

X-Seed® crystals from BASF make concrete harden faster and reduce carbon emissions

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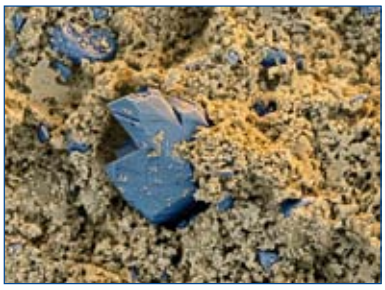
They're everywhere, although we hardly spare a thought for them in everyday life – precast concrete components. Whether it's bridge girders, sewer pipes, staircases or railway sleepers: millions of these structural elements are industrially prefabricated and installed directly on-site. With X-Seed, BASF has succeeded in introducing an important innovation in this area. Because this hardening accelerator not only allows precast concrete units to be produced more rapidly and in better quality, it also considerably reduces energy consumption and the associated emissions of the greenhouse gas carbon dioxide (CO_2).

How does it work? The main ingredient of concrete is cement, which is obtained by firing limestone, clay and minerals at high temperatures to produce cement clinker. This process consumes enormous amounts of energy. The coarse-grained clinker is finally ground into a fine, gray cement powder which hardens after mixing with water. Chemically speaking, calcium silicate hydrate (CSH) and other compounds crystallize out of the cement during this process to form a compact artificial stone in which the aggregate substances like sand and gravel also contained in the concrete are embedded.

Prefabricated components are produced by pouring the still liquid concrete into formwork molds made of wood, metal or plastic. Only when the concrete has hardened sufficiently can this casting mold be opened and the component removed. At ambient temperatures of around 20 degrees Celsius it takes around twelve hours until the concrete is hard enough – valuable time during which the formwork cannot be re-utilized. To speed things up, the liquid concrete is often heated with steam. Although this accelerates the hardening process, it also demands much additional energy. Moreover, this treatment can lead to internal thermal stresses, discolorations and a coarser surface of the finished concrete part.

"X-Seed makes heat curing with all its disadvantages largely superfluous," explains Dr. Michael Kompatscher, responsible for BASF's European precast concrete component market. "With this additive, concrete hardens just as fast at 20 degrees Celsius as it otherwise does at 60 degrees Celsius. And by a brilliantly simple method – because all it involves is adding something that's already present in the concrete anyway: calcium silicate hydrate." More precisely, it's the countless millions of tiny CSH crystals with a diameter of several nanometers suspended in liquid in X-Seed. Because of their nanosize, more very homogeneously distributed crystallization seeds can be accommodated in the same mass and thereby promote faster growth. When the concrete hardens, ▶

Concrete is now omnipresent. Worldwide, some 1.4 billion metric tons of cement are used to produce this hard artificial stone.



Nanoscale crystal seeds also make concrete harden faster at normal outside temperatures (magnification 960:1 at 12 cm image width).

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further molecules from the cement can attach themselves to these CSH seeds. The resulting crystals grow more densely and finally interlock to form the compact cement stone.

The mechanism of action of the hardening accelerator is explained by Professor Horst-Michael Ludwig of the Bauhaus University in Weimar: “As well as the temperature the availability of these crystallization seeds determines the rate of crystal formation and thus the hardening process. Normally, the CSH seeds first have to form spontaneously from several molecules released from the cement which accidentally come into contact with each other. X-Seed avoids this first barrier to crystallization by providing an excess of these tiny crystal seeds.” Another factor is that the CSH crystals form in a more homogeneously distributed manner, adds the expert for construction materials who early turned his attention to this subject. “Without the additional seeds, the crystals first form on the surface of the cement grains, which are soon enveloped by a crystalline layer that delays the exchange of water and of the molecules released from the clinker and so also slows down the further hardening process.”

Both these effects of the synthetic crystal seeds halve the time to formwork removal at 20 degrees Celsius from about twelve to six hours, without any detectable differences in the final product. This sounds simple in theory, admits BASF research scientist Dr. Luc Nicoleau who was centrally involved in the developing of X-Seed: “But the greatest challenge was to keep synthetic CSH crystals measuring only a few nanometers in a liquid suspension for prolonged periods without them fusing together and losing effectiveness.” The BASF experts finally succeeded in performing this impressive feat of process technology thanks to their many years of experience with the dispersion of ultrafine materials.

When X-Seed, which can simply be shoveled into the concrete mixer along with the other ingredients, was finally launched on the market in 2009, its enormous use potential immediately became apparent. Besides the large market for precast concrete components, in which manufacturers can now produce more efficiently and rapidly and handle peak workloads more flexibly, this innovative accelerator also offers advantages for a number of other applications. The product shortens the construction times of roads, tunnels and airstrips – also in winter outdoor temperatures. The nanoproduct X-Seed not only saves costs, it also has an extremely positive influence on the energy and climate balance and hence the sustainability of the material concrete (see Info box).

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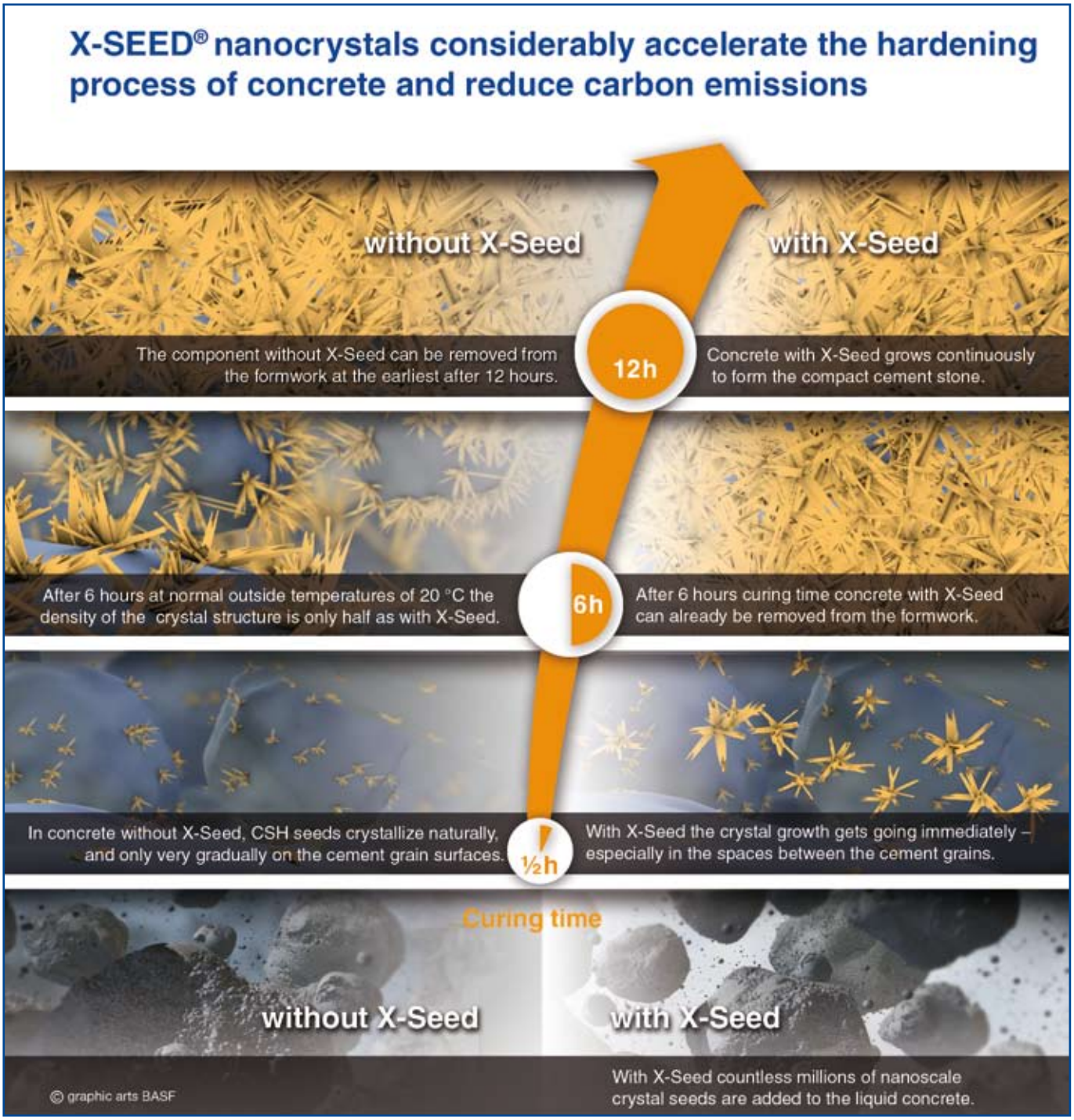

Further information can be found at:
http://www.basf.com/group/corporate/de/innovations/innovative-solutions/x-seed
http://www.uni-weimar.de/Bauing/fib

See Info Box ▶

Text, photos, interaktive graphic and animation with sound are available at: www.basf.de/science_around_us

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X-Seed on the sustainability test bench

The ecological, economic and social impact of X-Seed throughout its life cycle were investigated using BASF's SEEBALANCE®, **S**ocio**E**co**E**fficiency Analysis. This holistic evaluation method was designed to provide scientifically sound answers to two central questions.

1. Accelerated curing with steam consumes about 10 liters of heating oil per metric ton of concrete. X-Seed makes this superfluous. **What impact does this have in the sustainability comparison?**

- Ecological: The saving of heating oil for curing reduces not only carbon emissions but also the consumption of energy and resources.
- Social: Improved "social fingerprint" in all analyzed areas of concrete production. For example, X-Seed contributes to creating qualified and well-paid jobs.
- Economic: Overall, X-Seed saves more costs than its purchase generates.

2. Firing the cement clinker consumes large volumes of fossil fuels and releases great amounts of carbon dioxide. The International Energy Agency estimates that the increased use of low-clinker cements with a higher content of filler materials such as slag sand and fly ash could reduce these emissions by around 13 percent. But these cements take a lot longer to harden – a disadvantage that can be fully compensated with X-Seed. **What is the impact of the cement clinker reduction possible with X-Seed?**

- Ecological: Low-clinker cement with X-Seed saves energy and therefore reduces carbon emissions.
- Social: The mix of low-clinker cement and X-Seed has positive effects across all social evaluation parameters considered, for example due to the creation of highly qualified and well paid jobs in the chemical industry.
- Economic: Savings from lower-priced cement largely compensate the costs of X-Seed.

In addition to BASF's internal Seebalance analysis, together with the Freiburg Ecoinstitute the company has tested a completely new method for evaluating the sustainability of nanoproduction using X-Seed as an example. This "nanosustainability check" also demonstrated that X-Seed can contribute decisively to sustainable construction with concrete.