Concrete Plant International
Worldwide English Edition

3 | 2023

www.cpi-worldwide.com

REPRINT | CONCRETE TECHNOLOGY

New type of steel fibre for efficient and particularly sustainable construction components

REPRINT
CPI 3/2023

Bilstein Group, 58119 Hagen, Germany

New type of steel fibre for efficient and particularly sustainable construction components

Michael von Ahlen, CPi worldwide, Germany

The trend in the precast concrete industry is increasingly towards slender and resource-optimized components. One reason for this is the growing awareness of sustainable concrete construction and the demand for CO_2 savings across the various industry sectors involved. This trend is forcing us to rethink, not only in terms of material selection, but also in the design and construction of concrete members. In the future, precast concrete manufacturers will increasingly have to consider alternative component solutions in order to remain competitive. An approach that can assist with these matters is the use of fibre reinforcement because fibres can be used either as a complete replacement or as part of a hybrid solution, i.e., in combination with conventional reinforcement. Wherever steel reinforcing bars or mesh reinforcement do not efficiently meet the requirements for the load-bearing behaviour of concrete components, fibres can provide the method of choice. Used correctly, fibres improve the mechanical properties of concrete and enable material savings. The improvement of production processes related to preparatory work and installation is another advantage of fibre reinforcement. In April this year, the Bilstein Group from Hagen in Germany, a global leader in cold-rolled special steels, for example for the automotive and saw/tool manufacturing industries, launched a new steel fibre type on the market. The innovative design holds the promise of an efficient and particularly sustainable reinforcement solution for the precast concrete industry.

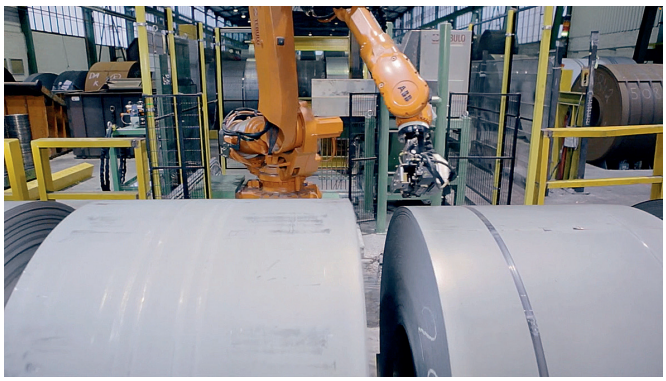
Fibre reinforcement has been available on the market for about 50 years as an alternative to conventional steel reinforcing bars. But what distinguishes individual fibre types from each other? Basically, the functional principle is always the same: A fibre, whether made of steel, carbon or glass, must be anchored in the concrete matrix in order to be able to transmit tensile forces, which the concrete itself can only absorb to a limited extent. If the concrete member cracks in a location where a fibre is orientated relatively orthogonal to the crack trajectory, the fibre takes over the tensile forces. Fibre-reinforced concrete components are characterized by a very finely distributed crack pattern with very small crack widths. Depending on the application, fibres improve the hardened concrete properties such as tensile strength, impact strength, ductility, cracking behaviour and possibly also the fire resistance.

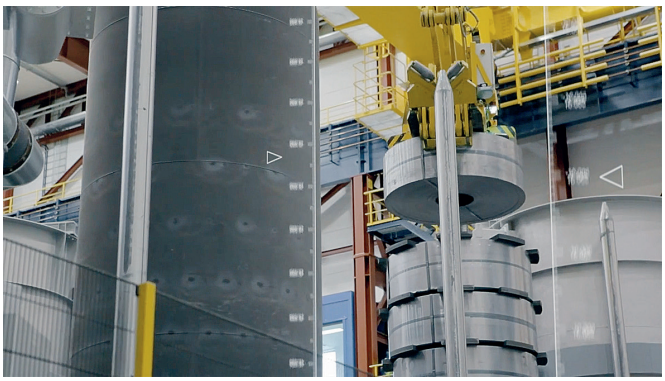
The Stabils steel fibre, which was launched in April of this year, differs significantly from other steel fibres. This is already obvious at first glance, because it has a consistently straight shape.

In addition to the various fibre materials, there are also different fibre geometries. Not only the slenderness ratio (l/d ratio), but also the geometry of the fibre ends varies greatly, especially with steel fibres. The fibre orientation in the finished concrete member plays an essential role in the assessment of structural effectiveness, whereby the fibres should ideally be aligned parallel to the tensile stress direction.

With the official launch of Stabils steel fibres at BAU in Munich in April this year, Bilstein Steel Fiber GmbH, a company of the Bilstein Group, presented a new fibre type to the concrete construction industry. Already at first glance, the Stabils fibre differs significantly from other steel fibres because it has a consistently straight shape. Small anchor knots at the ends characterize the fibre and provide significant anchoring in the concrete.

Before introducing the fibre to the market, Bilstein initiated extensive investigations to verify its performance. The engineering consultancy KHP Leipzig and TU Graz developed numerous structural designs that were required for the development of the fibre. Fresh concrete workability and processability tests were carried out in cooperation with the Schwenk





Stabils steel fibres are manufactured in a state-of-the-art production facility. The Bilstein Group has many years of expertise in the field of materials and process engineering.

Technology Centre of Schwenk Zement in Allmendingen, Germany. In addition, Vetra Betonfertigteile GmbH, based in Neermoor, Germany, cooperated with field verification for the testing in a real production plant environment.

The fibre material

The Stabils steel fibre with the designation SB 60/70 - 2000 is manufactured from strip steel in a 3-step process including tempering. "SB" stands for the product name Stabils, "60/70" refers to the fibre length of 60 mm and the slenderness ratio (l/d ratio) of 70. "2000" refers to wthe tensile strength of the fibre. The fibres will be certified according to EN 14889-1 and ASTM A820/A820M-04. CE certification is planned for mid-2023.

The specially tempered steel is intended to make the fibre particularly effective and thus economical. The principle of fibre pull-out before fibre fracture always applies in order to ensure a ductile fracture behaviour of the concrete component. This means that the difference between pull-out and tensile strength of the fibre is very small.

Jörg von Prondzinski,
Head of Application Technology/
Application Development,
Bilstein GmbH & Co. KG

"With our many years of expertise in the field of materials and process engineering, we are able to adapt the Stabils steel fibre to specific application properties, e.g., with regard to the length of the fibre, the design of the anchor nodes or the adaptation of the strength and deformation properties of the fibre material. We have long strived to optimize the sustainability of our products. Another important step on this path is the participation in the H2 Green Steel Consortium, which is currently building a steel mill in Sweden using an innovative technology that allows the CO_2 footprint of the material to be reduced by up to 90%."

Characteristic geometry of the Stabils steel fibre – especially the formation of the fibre ends is a special feature.

The fibre geometry

The performance of the Stabils steel fibre is based on the optimum effective length and the unique fibre geometry, whereby very high values are achieved for the performance classes L1 and L2 defined in the steel fibre concrete guideline of the DafStb (German Committee for Reinforced Concrete). The performance classes are a meaningful guideline for the post-cracking tensile strength of concrete components.

According to the specific application requirements, the specifically manufactured anchor nodes can be varied in number, shape, size, and position. This variability is an enormous advantage, because the pull-out resistance can be directly influenced by the shape of the fibre. Application-specific differences in fibre geometry can for example be considered depending on whether the fibre is used as the sole steel reinforcement or as part of hybrid reinforcement or depending on the application in either shotcrete or tunnel segments.

The fibre geometry also results in advantages with regard to fresh concrete workability, whereby the Stabils fibres enable a higher maximum fibre content. A high content of steel fibres is usually considered difficult for two reasons. Already when mixing the fresh concrete, clumping can occur. This can only be eliminated, if at all, by very long mixing. In addition, a high steel fibre content can lead to interlocking of the fibres when

Dr. Michael Reichel, Partner at KHP Leipzig GmbH

"Due to its nature, the Stabils steel fibre can be adapted in such a way that it is pulled out of the concrete matrix shortly before reaching its maximum steel tensile strength. Thus, it can be optimally designed for every application. The superior performance of the fibre is reflected in very high values for the post-cracking flexural tensile strength, and thus in the load-bearing capacity of the concrete members themselves. As a result, concrete sections can be dimensioned with higher slenderness and with a higher material efficiency, saving valuable resources and increasing economic efficiency. From a structural design point of view, even the sole use of Stabils steel fibres for structurally relevant components is possible, which is however still limited by the current regulations. The areas of application of the fibres are almost unlimited. Wherever sustainable construction is important, the use of these fibres can be beneficial. The Stabils steel fibres are also ideal for components for which a defined crack width limitation is specified."

the concrete is cast into the formwork, resulting in poor flow properties of the fresh concrete. This means that small quantities of steel fibres bundle up and get stuck on formwork edges or reinforcing bars, thus significantly hindering the flow of concrete in the formwork. And for this case, too, the Stabils steel fibre can score points: even at higher fibre contents of more than 60 kg/m³, the fresh concrete shows very good workability with regards to mixing and flow properties, which is particularly important for combined reinforcement.

The range of applications

In principle, the Stabils steel fibre is suitable for all kinds of concrete applications. However, the focus in the development of the fibre was on structural precast concrete elements. This is where steel fibre can fully demonstrate its strengths, especially when it comes to the production of resource-efficient components with slender cross-sections.

For slender structural components, combined reinforcement is usually necessary. Due to the small component dimensions and small distances between formwork surface and conventional reinforcement, there is little space left for the fresh concrete, which must flow well within the formwork. Above all, the flow of fresh concrete is significantly influenced by the type and quantity of the fibres. The influence of the fibres on the workability of the concrete is crucial for the final product – the concrete component.

Laboratory investigations

In the Schwenk Technology Center of the company Schwenk Zement extensive tests were carried out to determine the processability of the Stabils fibres. The influence on the mixing process, the consistency and the flow behaviour of fresh concrete were examined. The flow properties were tested in a formwork arrangement representing typical practical applications. Conventional reinforcement was included in order

Thomas Arndt, Head of Testing Centre, Schwenk Technologiezentrum GmbH & Co. KG

„The purpose of the laboratory tests was to investigate the flow behaviour of the Stabils steel fibres when used as combined reinforcement. The selected fibre contents of 40 and 60 kg/m³ are based on the existing design of precast concrete elements, aiming at achieving the required L1 and L2 values. The tests show that fibre contents of more than 60 kg/m³ can be implemented in practice in conjunction with combined reinforcement."

The use of steel fibres supports resource-efficient construction methods. On the left a staircase with conventional reinforcement, on the right a staircase with a combination reinforcement with the same performance characteristics.




Extensive test program to determine the processability of the Stabils fibres in the Schwenk Technology Center of the company Schwenk Zement.

to simulate combined reinforcement. Numerous tests have shown, among other things, that even with high steel fibre contents of 60 kg/m³ and more, good processability is still guaranteed.

Testing in the production plant

The precast manufacturer Vetra Betonfertigteile GmbH is working intensively on the question of how to reduce CO_2 in construction. One approach that the company pursues is the optimization of precast concrete elements through design and targeted selection of constituent materials.

This led Vetra to rethink not only the optimization of mineral materials such as cement and aggregate, but above all the reinforcement of the concrete members. Steel is a particularly CO_2-intensive material, whereby even the reduction of small quantities can lead to a measurable improvement in the overall ecological footprint of the component. The solution: combined reinforcement made of reinforcement mesh or bars and steel fibres.

At the beginning of March this year, tests were carried out at Vetra to examine standard components in the production portfolio with regard to CO_2-optimisation. For this purpose, the characteristics of a half-spiral staircase from regular production were set as reference values. The reference component had conventional steel reinforcing bars and mesh reinforcement. However, the structural function of the staircase remained the same.

Table 1: Comparative characteristics of stair components.

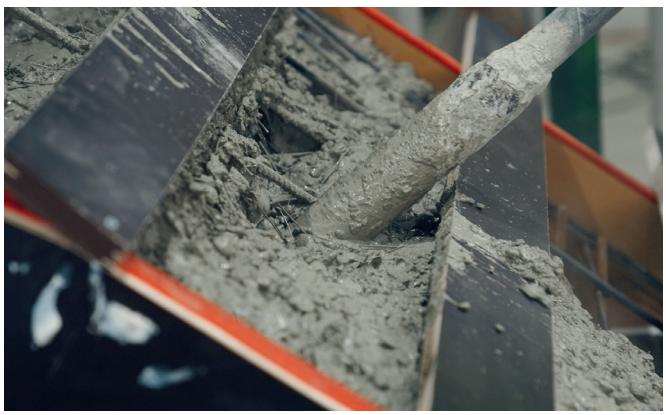
Comparison of a semi-spiral concrete staircase		
	Standard	**CO_2-reduced**
Staircase weight [kg]	3720	2860
Amount of concrete [m³]	1.49	1.14
Conventional reinforcing steel [kg]	188	68
Stabils steel fibres [kg/m³]		30
Compressive strength class	C30/37	C35/45
Formwork preparation [h]	20-22	20-22
Rebar installation [h]	12-15	1-2
Concreting [h]	2.5	2.5
Saving in CO_2		**19 %**




Production of a CO_2-reduced staircase using a combination reinforcement with the Stabils steel fibre. The fresh concrete with a steel fibre content of 30 kg/m³ can be easily installed in the formwork.

In the first experiment, a CO_2-reduced staircase was produced using a combination reinforcement. The quantity of Stabils steel fibres added (SB 60/70 – 2000) was 30 kg/m³ (Table 1). By adding the steel fibres, it was possible to reduce the conventional reinforcement for the entire component by approx. 120 kg (corresponding to around 65%). This also made it possible to save on the quantity of concrete. The amount of concrete required was reduced by about 25%. Although the CO_2-reduced staircase was made with a higher-quality cement, the cement also resulted in less CO_2 compared to the reference mix.

In addition to the material savings, significant savings in the installation time of the reinforcement could also be demonstrated. Here, the effort was reduced by 80-90% since the installation of the conventional reinforcement was limited to an absolute minimum and the steel fibres entered the component without any loss of time when the concrete was cast. Compared to the reference concrete, the installation of the steel fibre concrete was problem-free and not related to any time disadvantages. The steel fibre used here had a length of 60 mm. A Stabils steel fibre with a length of 50 mm optimized for use in combination reinforcement is already in preparation at Bilstein and should be available on the market shortly.



The installation of the fresh concrete with the Stabils fibre proves to be very simple. The fibres show a very homogeneous distribution in the fresh concrete and no tendency to clumping.

Stefan Gramberg, Manager, Vetra Betonfertigteilwerke GmbH

"At Vetra and also at Holcim Germany, we are trying to make tomorrow's construction CO_2-free. In the production of precast concrete elements, we follow this approach through design optimization and the targeted selection of constituent materials. The staircase component is a great example, based on which traditional concepts can be compared with a sustainable and innovative concept. Using the Stabils steel fibre, we can significantly reduce the required amounts of both steel and concrete. This allows us to produce components that have the same performance but need fewer materials."

Lifting of the CO_2-reduced precast concrete staircase. By using a combination reinforcement, the staircase can be manufactured very material-efficiently.

The total weight of the CO_2-reduced staircase was significantly lower than that of the reference staircase. The savings here: around 25%! This in turn results in advantages in terms of transport costs and logistics in the concrete plant as well as on the construction site.

Environmental and economic benefits

The Bilstein Group takes the current challenges of climate protection very seriously and wants to become climate-neutral by 2035. However, the plan does not stop at the provision of constituent materials for the production of CO_2-optimised precast concrete elements. Another important step towards a positive climate balance is the participation in the H2 Green Steel consortium, which is currently building a steel mill in Sweden with an innovative technology that allows the CO_2 footprint of the material to be reduced by up to 90%. With this constituent material, Bilstein will be able to place the Stabils steel fibre on the market as an extremely sustainable reinforcement solution.

Michael Ullrich,
Manager, Bilstein Group

"Following intensive research and market analyses, we decided last year to invest in plant technology for steel fibre production. Our market entry is divided into three phases. In phase one, with an annual production volume of 1000 tons, the Stabils steel fibres are to be used primarily in precast concrete elements for wastewater management. In the second phase, with a production capacity of approximately 15,000 tons per year, which is scheduled to run from mid-2025, the application of the fibres will include pavements, large precast concrete elements and tunnel components. The third phase then additionally focuses on the application in shotcrete. Our target markets are initially the surrounding European area, but later also other regions, such as North America."

Target markets

The introduction of Stabils steel fibre is divided into three project phases. In phase 1, Bilstein, with a production capacity of approx. 1000 metric tons per year in 2023/2024, will keep the Stabils steel fibre ready for applications in various structural precast concrete elements, pipes and shaft structures. The availability is limited to Germany and other European countries. Phase 2, which is scheduled to run from mid-2025, is planned for use in pavements, large precast concrete elements, such as prestressed concrete trusses and tunnel components (segments). Annual production is then expected to rise to approximately 15,000 tons per year. The third and for the time being final phase focuses on the application in shotcrete. Following the successful market launch, other markets, such as North America, are also on the Bilstein Group's agenda. ■

FURTHER INFORMATION

BILSTEIN STEEL FIBER

STABILS
PERFORMANCE FOR CONCRETE

BILSTEIN GROUP
Im Weinhof 36
58119 Hagen, Germany
T +49 2334 82-0
stabils@bilstein-steelfiber.de
www.bilstein-steelfiber.de

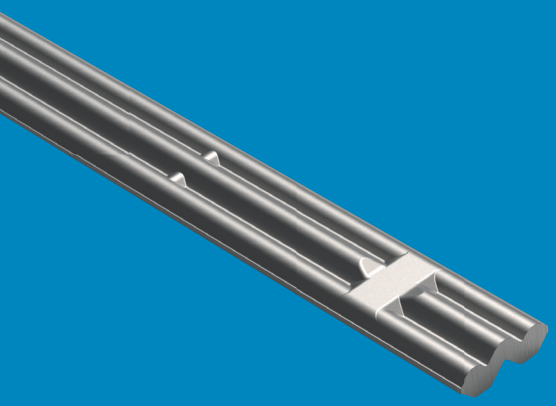
Cooperation partners

HOLCIM
www.holcim.de

KHP LEIPZIG
www.khp-leipzig.de

SCHWENK
www.schwenk.de

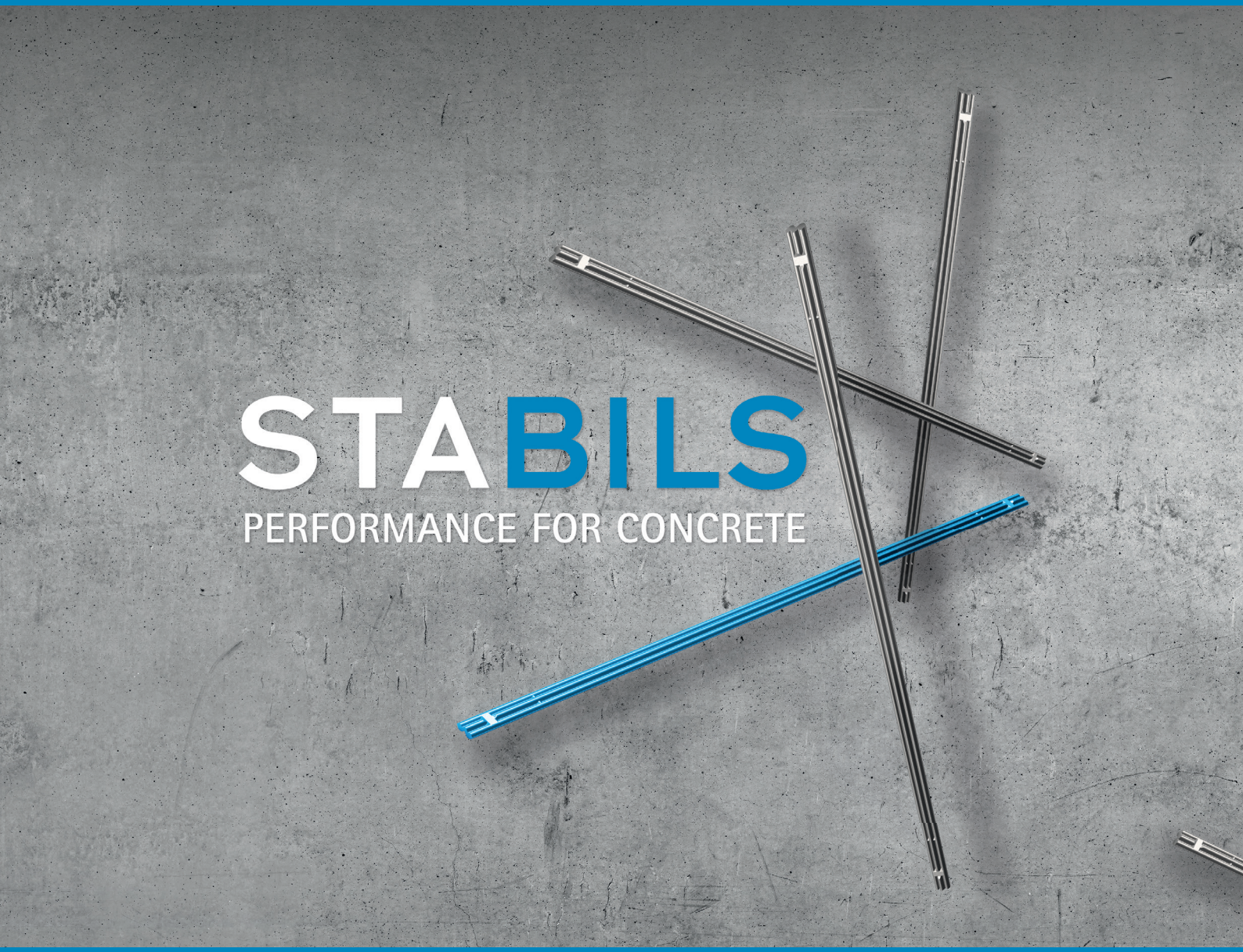
New generation of steel fibers



Application flexibility for complex structures and small concrete components

Less concrete and CO_2 due to thinner components

Homogeneous fiber distribution even with hybrid reinforcement



bilstein-steelfiber.de

BILSTEIN STEEL FIBER
A BILSTEIN GROUP company