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Steel-Fibre Concrete – A Replacement for Conventionally Reinforced Concrete?

Steel-fibre concrete is a modern composite material, whose overall characteristics are great toughness and low crack sensitivity. For the production of steel-fibre concrete, steel fibres having different geometric shapes and surface characteristics are used in order to provide the concrete with properties adapted to the individual field of application. Steel-fibre concrete is used for the production of structurally reinforced construction elements.

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Keywords

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Steel-fibre concrete is a concrete composite material to which steel fibres are added in order to obtain ready-mixed concrete featuring certain properties. In addition to steel-fibre concrete, fibre concrete containing plastic- or glass fibres is produced. For more than 20 years, steel-fibre concrete has mainly been used in system building construction. In the past ten years, site concrete with added steel fibres has also been used as a material for the production of a growing number of various construction elements.

In this case, reinforcement quasi comes out of the concrete mixer truck. In addition to time- and cost savings, which result from the fact that no installation time is needed for the reinforcement, the main arguments for the use of steel-fibre concrete are the improved properties which are obtained thanks to the added steel fibres, such as

- greater wear resistance
- better shrinking behaviour
- greater crack resistance and reduction of crack propagation in micro-crack formation
- greater impact resistance.

The fibres differ from one another due to their form and material properties, which also determine their general possibilities of use:

- *Milled and stamped fibres* have a large surface and are characterized by a large number of fibres per kg. These fibre types are generally approximately 30 mm long and about 0.4 mm thick. They are mainly used to increase crack resistance (shrinkage crack reduction) in uncracked concrete (condition I).
- *Wire fibres* are made out of cold-drawn wires of different material quality and fibre shape. The length of the fibres produced ranges from 12 to 70 mm, and their diameters vary between 0.15 and 1.20 mm. Steel fibres in a corrugated form or end anchorage improve the properties of the ready-made concrete in a cracked condition (condition II).
- *Sheet metal fibres* are made out of cold-pressed sheet steel. Fibre lengths range from 12 to 50 mm. Through imprinting, adhesion between fibres and concrete is improved, which results in greater crack resistance. As compared with wire fibre, however, only little tensile stress is transmitted in cracked concrete.
- *Stainless steel fibres* are made out of steel wire and sheet steel. Due to their great corrosion resistance, they are used for the production of outdoor construction elements, for example.

Steel fibres require general building regulation approval by the German Institute for Construction Technology. The relevant standard for the design of construction elements out of concrete is DIN 1045. For the handling of steel fibre concrete, the following supplementary regulations apply:

- Instructions of the German Concrete- and Construction Technology Association (DBV)
- "Steel fibre concrete" guidelines of the German Committee for Steel Concrete (DAfStb).

The minimum fibre content is indicated in the approval of the individual fibre type. In general, the fibre content of steel fibre concrete elements ranges between 20 and 80 kg/m^3. At a fibre content of more than 50 kg/m^3, working properties deteriorate noticeably. For reasons of production technology and depending on the kind of fibre, the upper limit ranges between approximately 100 and 150 kg/m^3. Concrete with higher steel fibre contents can no longer be mixed. In addition, it cannot be used for construction and compacted properly.

Production and Areas of Application

The steel fibres are added to the concrete in the mixer station during production or in the mixer truck. After the fibres have been added, construction consistency is adjusted using concrete plasticizer. Given normal consistency, steel fibre concrete can be pumped like normal concrete up to a fibre content of 40 kg/m^3.

When constructing hall floors, the concrete can be spread in one work step because no mat reinforcement needs to be installed.

Construction elements out of steel fibre concrete can be used like normal concrete in

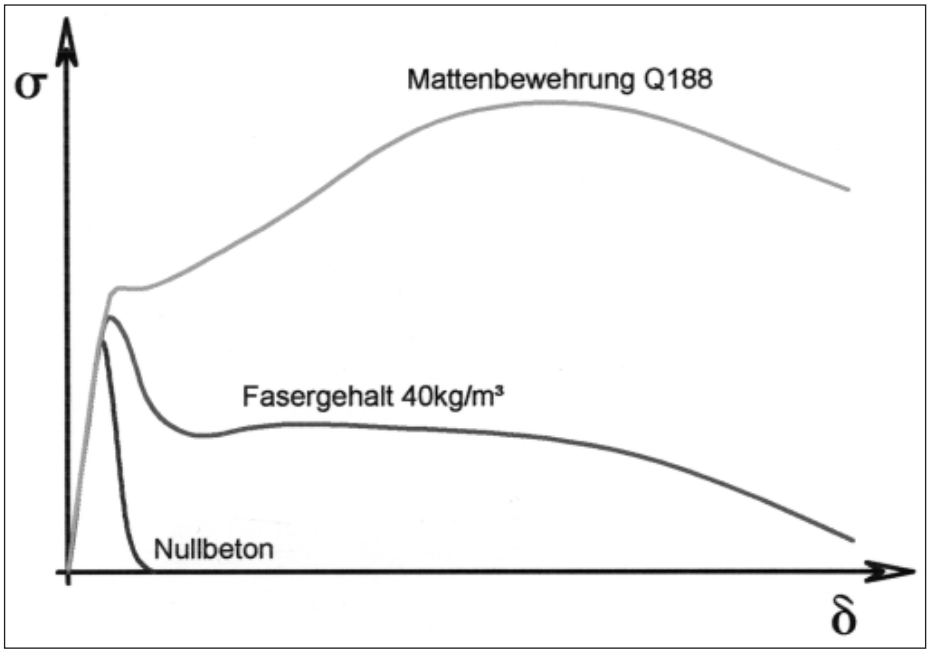

Fig. 1: Schematic presentation of the behaviour of non-reinforced concrete, steel-reinforced concrete and steel-fiber reinforced concrete under centric tense. The different failure behaviour of the three concretes is clearly recognisable. Ordinary concrete (Nullbeton) breaks brittly.In the steel-fiber concrete (Fasergehalt 40 kg/m³) composite between fiber and concrete fails, so it can not keep the tension. In steel-reinforced concrete the concrete steel resists and the tension rises until the steel tears

a weathered or corrosive environment.

Steel fibres in concrete are corroded down to a depth of approximately 4 mm. If exposed to chlorides, the fibres are susceptible to corrosion down to a depth of 10 mm. Due to the small measurements, however, spalling caused by volume enlargement of the corroded steel fibres does not occur.

In the case of heavier chemical corrosion, stainless steel fibres should be employed. In order to avoid rust stains, construction elements out of steel fibre concrete which are used in the façade area should also be produced using stainless steel fibres.

Due to the three-dimensionally arranged steel fibres, which are distributed over the entire cross section, the toughness of this ready-made concrete is unequalled by conventional steel concrete. Higher fibre contents also result in greater resistance to crack formation (condition I) under load than in conventionally reinforced concrete. In a cracked condition (condition II), where conventional reinforcement begins to have a stabilizing effect, steel fibre concrete quickly loses its stength, which leads to failure. The unfavourable post-cracking behaviour of steel fibre concrete is caused by the steel fibres losing their adhesion with the concrete and ripping out due to their short lengths. As a consequence, the construction element cannot withstand the built-up stress and fails. Fibre contents at which the rupturing behaviour of steel fibre concrete comes close to that of conventionally reinforced steel concrete exceed 200 kg/m^3 and are thus outside the range applicable in practice. In a static sense, construction elements out of steel fibre concrete cannot be considered supporting and are only able to absorb forced and internal stress (e.g. from heat generation during setting or shrinking). Therefore, steel fibre concrete is primarily used in structurally reinforced construction elements.

To put it simply: steel fibre concrete can be used for all applications where health and life are not in immediate danger. Only those prefabricated steel fibre concrete parts and techniques which have been examined and approved by the Institute for Construction Technology in Berlin form an exception.

In the industrial area, steel fibre concrete is currently being used for the construction of
- industrial floors
- concrete pipes
- walls
- ram piles and
- as jetcrete for tunnel linings and slope consolidation, for example.

Application in Rural Construction

Currently, the main area of application of steel fibre concrete in agriculture is the construction of floors in storage halls. Here, the use of steel fibre concrete provides a significant improvement in the required properties, such as flawlessness as well as impact- and wear resistance. As mentioned above, its production is also economical.

Since it is largely free of cracks, steel fibre concrete can be used in areas where tightness plays a particular role, e.g. in the construction of
- dung plates and
- filling places of farm petrol stations

whose construction requires the use of concrete impermeable to water.

The area of application of steel-fibre-reinforced concrete ends where structural reinforcement for crack width limitation is no longer sufficient and static proof of necessary reinforcement is required.

Evaluation

Thanks to its properties, steel-fibre concrete is a material which finds its application as a replacement of structurally reinforced concrete. Steel fibres can replace mat reinforcement up to size Q188. Post-cracking behaviour should not be significant for the fitness for use of the construction elements.

Despite the relatively high price of € 135,- to € 155,- per m^3, the costs of steel fibre concrete are quite competitive as compared with conventional concrete, which results from its above-described advantages. In agriculture, steel-fibre concrete can be used for the construction of durable concrete plates impermeable to liquids. Despite its positive properties, steel-fibre concrete cannot be used for the construction of feed silos because the feed might be contaminated with detached steel fibres. As the fibre content increases, the compaction behaviour of steel fibre concrete deteriorates, which reduces its ability to be used for construction work carried out by the owner.

Literature

Books are identified by •
[1] - Merkblätter des VDS, Verband Deutscher Stahlfaserhersteller
[2] • *Pfyl, Th.*: Tragverhalten von Stahlfaserbeton. Dissertation, Technische Wissenschaften ETH Zürich, 2003, Nr. 15005 (http://e-collection.eth-bib.ethz.ch/show?type=diss&nr=15005)
[3] • *Rosenbusch, J.*: Zur Querkrafttragfähigkeit von Balken aus stahlfaserverstärktem Stahlbeton. Dissertation, TU Braunschweig, 2003, Nr. 475
[4] *Pockes, Chr.*: Internetseiten, FH Deggendorf, www.fhdeggendorf.de/biw/studenten/jg1995
[5] - : DAfStb-Richtlinie Stahlfaserbeton, Deutscher Ausschuss für Stahlbeton, März 2003
[6] - : Merkblatt Stahlfaserbeton, Deutscher Beton- und Bautechnik Verein e.V., Oktober 2001
[7] - : SIA 162/6: Stahlfaserbeton, Schweizer Ingenieur und Architekt