Carbon Concrete Composite

Fact Sheet

# Carbon concrete

Publisher: C³Verband (C³Association)
Dresden, February 2024

# Building with reinforced concrete

The creation of living space and infrastructures is essential for our quality of life. Concrete is the construction material most used across the world. However, concrete can only absorb high pressures but almost no tensile forces. For this reason, structures made of concrete must have a high-tensile material built into them, a so-called reinforcement. Since the end of the 19th century, steel has been the preferred material for this purpose, as expressed by the German term for reinforced concrete – "steel concrete".

There is a decisive disadvantage to reinforced concrete constructions: steel corrodes! To avoid corrosion in concrete, a high-alkaline environment must be created, and the concrete must serve as a protective medium. Accordingly, concretes with a high cement content are usually used. In addition, a quantity of concrete going beyond the structural requirements must be applied, the so-called concrete cover. Consequently, as one of the world's largest $CO_2$ emitters and consumers of resources, concrete construction work is being regarded more and more as a climate killer.

Use of carbon concrete for the field of renovation, repairs and strengthening (bridge arch in Naila) | © A. al Jamous

# Building with carbon concrete

**Approach**

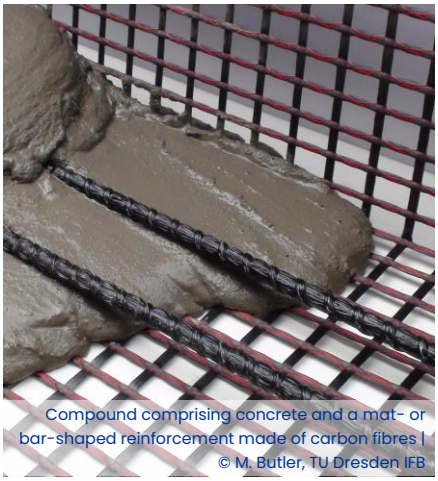
-

Carbon concrete is a composite material made of concrete and a non-metallic reinforcement made of carbon fibres (carbon), or even glass or basalt. The reinforcement containing carbon fibres is made up of a fibre based on carbon, sizing agent and impregnation. The crucial factor is that the reinforcement is executed as either mats-, meshes- or bar-shaped, whereas short fibres mixed into the concrete do not make carbon concrete.

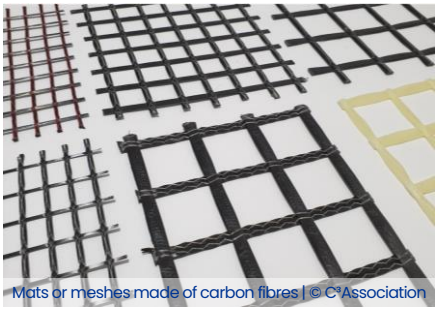
All concretes established or newly developed for the building and construction industry – within the context of currently valid standards or with approval certificate – can be used for carbon concrete. The mixing ratio, especially the particle distribution, must match the reinforcement used.

The distinctive feature is in the carbon-based fibre, which has a tensile strength of up to 6,000 N/mm², whereby the fibres used in the building and construction industry so far have a tensile strength of approx. 4,000 N/mm² (and thus eight times higher than steel). The elastic modulus of such a fibre is around 210,000 to 230,000 N/mm², which is comparable with steel. On the other hand, its density is only around a quarter of that of steel, which means it is four times lighter than steel per cubic metre. In addition, such a carbon-based fibre cannot corrode, it is resistant to chloride and does not require an alkaline environment.

The mat or mesh reinforcements are manufactured using a textile process. Size, cross-section of the reinforcement and the roving as well as the distance between the rovings can vary. Depending on the impregnation, mats or meshes are rigid or easily ductile and can be purchased flat or wound onto coils.



Compound comprising concrete and a mat- or bar-shaped reinforcement made of carbon fibres | © M. Butler, TU Dresden IFB



Mats or meshes made of carbon fibres | © C³Association

Bars made of carbon fibres | © C³Association

**Contact**
**C³ — Carbon Concrete Composite e. V.**
WTC Dresden, Ammonstraße 72 | 01067 Dresden, Germany
carbon-concrete.org • info@carbon-concrete.org • +49 351 48 45 67 00

**Dr.-Ing. Stefan Minar**
s.minar@carbon-concrete.org • +49 351 48 45 67 19

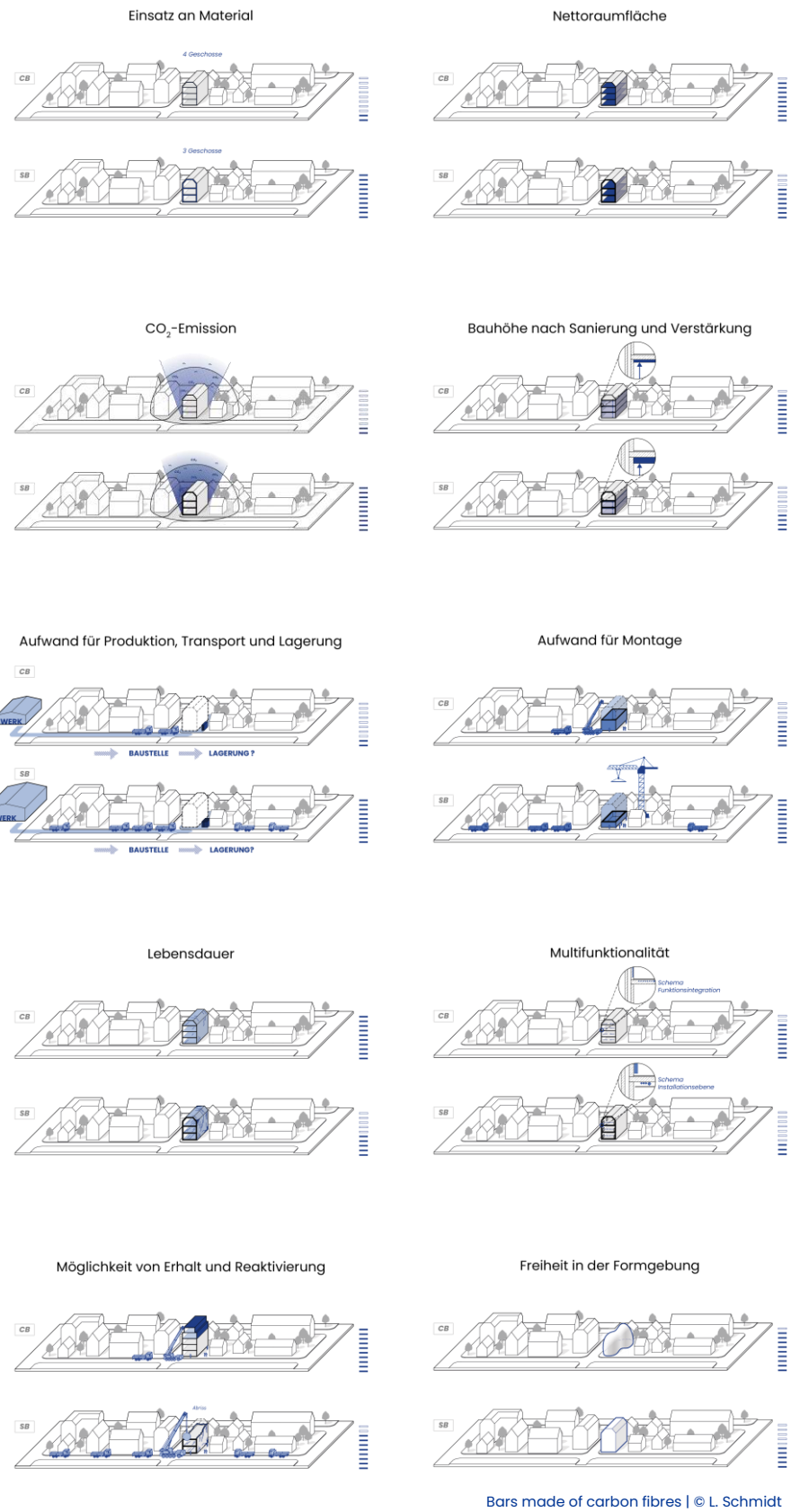
In contrast, the bar-shaped reinforcements are manufactured using a pultrusion technology process. The surface is profiled by means of winding, milling, embossing and/or sanding. Bars are available in different lengths, diameters (usually over 6 mm) and in any bent shape (hoop). It is not yet possible to bend bars on site and in precast element plants. Bars can be connected into mats with individual spacing. In addition, there are carbon fibre tension strands where several yarns are twisted together.

### Advantages

-

Fortunately, building with carbon concrete is already an economical alternative in today's building and construction industry. The members of the C³Association alone have named more than 200 applications where carbon concrete construction is being used for new builds as well as for renovation, repairs and strengthening. With a view to building with concrete, the use of non-metallic reinforcements has a positive influence on a range of different aspects of the building and construction industry, whereby their extent depends on the individual application. In comparison to existing structures made of reinforced concrete, the carbon concrete construction method is characterised by the fact that

- up to 80 % material (sands, water and cement, sometimes doing without surface protection systems) is saved. This is due to slimmer structures, the reduction of the concrete cover to protect the reinforcement from corrosion in new builds to a minimum of 10 mm instead of 55 mm, and in the case of renovation, repairs and strengthening application of a concrete layer with a minimum dimension of 15 mm instead of 80 mm.
- up to 80 % less $CO_2$ is emitted, but this depends on the amount of resources used, the use of ecological concretes and the adapted effort during loading and transport.
- on average 50 % and ultimately up to 80 % of the resources for loading




Bars made of carbon fibres | © L. Schmidt

**Contact**
**C³ — Carbon Concrete Composite e. V.**
WTC Dresden, Ammonstraße 72 | 01067 Dresden, Germany
carbon-concrete.org • info@carbon-concrete.org • +49 351 48 45 67 00

**Dr.-Ing. Stefan Minar**
s.minar@carbon-concrete.org • +49 351 48 45 67 19

(forklift, crane, etc.), transport (fuel, cargo area, etc.) and storage areas is saved since the useful load per component is lower.
- a service life of 200 years – and thus four times longer – is to be expected due to the resistance against corrosion and chloride penetration. 100 years are already being verified within the context of approvals.
- dilapidated objects from building, structural and civil engineering can be preserved and reactivated, where other construction methods reach their performance limits due to the requirements of the additional dead weight or the restrictions on listed buildings.
- up to 8 % more space can be gained inside for sale, rent or own use since the net room space is larger with identical gross floor space. As a result, construction costs per square metre of useful space can be reduced. In addition, more space in a warehouse, silo, store, etc. leads to more storage space and thus lower costs per cubic metre of useful volume.
- lower building heights can be achieved, leading to new approaches being realised for the construction of passages for bridges and rivers, passage heights in tunnels and garages as well as room heights in buildings. Subways for footpaths and cycle paths may only be retained in this way after renovation, repair and strengthening, whereas an additional floor can be realised in the new build.
- handling materials and components is much easier, particularly in terms of the light and flexible carbon reinforcement. It is usually possible for a single person to carry such reinforcement without lifting gear (forklift, crane, etc.), and it also makes working overhead easier. Light tools can be used for cutting the reinforcement.
- the reinforcement can be used for surface heating (wall or floor heating) at the same time, since it is electrically conductive and has high resistance. Equally, an additionally mounted reinforcement made of carbon can serve as cathodic corrosion protection.
- new design aesthetics are possible with regard to thin, curved or even bionically shaped components which have previously not been able to be implemented in this variety.

**New builds**

-

Components and structures made of carbon concrete are no longer built only when special requirements are made on corrosion protection. Thanks to the low use of material and thus a reduction in weight, individual components made of carbon concrete can also be installed under difficult access conditions (high, narrow or scaffold-free access, etc.). The respective components are manufactured in precast element plants and on site.

(Semi-)finished components are mainly produced in precast element plants, since this is the only place where constant optimum general conditions with regard to internal (quality checks, etc.) and external environmental influences (weather, etc.) are given. For economical building with carbon concrete, members of the C³Association optimise the completely automated process which is similar to the usual processes in concrete construction. First, mat- and bar-shaped reinforcements are made from carbon (textile- and robot-oriented procedure), then spacer elements are attached to the reinforcement (robot-oriented procedure), then reinforcements are inserted into the formwork (robot-oriented procedure) and finally concreted in place (casting process). In addition, the degree of automation is increased, at the same time as the implementation of individual requirements during production, so that the former advantage of reinforced concrete in this area is quickly disappearing.

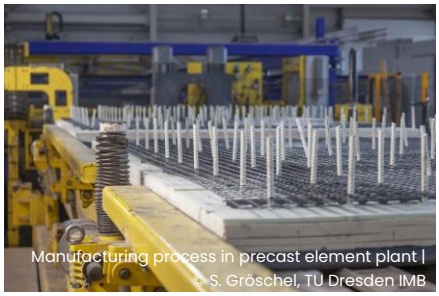
The construction site installation of the connections for (semi-)finished components can be realised by cast in-situ concrete. More unusual designs can be implemented individually on site. The work on site is easier to perform due to the material's characteristics (attachment of reinforcements on vaults, working overhead, etc.).

**Renovation, repairs and strengthening**

-

In some cases, renovation, repairs and strengthening using the carbon concrete construction method represent the only constructive and economical alternative to prevent existing buildings being demolished or deconstructed. Compared to reinforced concrete construction, the load-bearing capacity of existing structures can be significantly increased compared with a layer of carbon concrete only a few millimetres thick. The structure's dead weight is only slightly increased. The geometric dimension is retained to a major extent and the appearance is thus unchanged. As a result, numerous listed building infrastructures as well as monocoque and dome constructions with a dead weight close to the limit have already been strengthened and renovated.

Thanks to the general technical approval CARBOrefit®, extended in 2021, there is a solution available for planners and executors in the building and construction



Manufacturing process in precast element plant | © S. Gröschel, TU Dresden IMB

Spraying method on the construction site | © J. Singer

**Contact**
**C³ — Carbon Concrete Composite e. V.**
WTC Dresden, Ammonstraße 72 | 01067 Dresden, Germany
carbon-concrete.org • info@carbon-concrete.org • +49 351 48 45 67 00

**Dr.-Ing. Stefan Minar**
s.minar@carbon-concrete.org • +49 351 48 45 67 19

industry to implement this solution barrier-free. The basic structure and work steps are based on the established procedure for sprayed concrete. The surface of the old concrete is prepared first (cleaning and roughening). Then the first layer of concrete is applied using the spraying or lamination method. Next the mat-shaped carbon reinforcement is worked into the fresh concrete. Then the next layer of concrete is applied, whereby this process must be repeated as often as necessary until the number of layers required by the structural analysis has been reached (usually two or three). Finally, the cover layer must be applied after the last layer has been worked in. Another special feature is that no plugging is necessary for post-treatment of the composite joint.

### Codes and guidelines

-

Although building with carbon concrete is mainly characterised by innovative construction products or types, existing codes and guidelines make planning and building with carbon concrete easier. Alongside the provision of relevant documents by the C³Association, the following contributions have been made, for example:

- The German Institute for Construction Bautechnik – DIBt) lists general technical approvals (abZ) and/or general type approvals (aBG) in the environment of non-metallic reinforcements in concrete construction.
- The German Committee for Reinforced Concrete (Deutscher Ausschuss für Stahlbeton – DAfStb) has published a DAfStb guideline "Concrete components with non-metallic reinforcement" as a white paper which regulates dimensioning and the testing concepts for the field of new builds among others.
- The German Institute for Quality Assurance and Marking (Deutches Institut für Gütesicherung und Kennzeichnung – RAL) has published a registration for construction with carbon concrete (RAL-RG 351), so that in the building and construction industry, only those types of carbon fibres are used for mat- and bar-shaped reinforcements in concrete construction work which, on account of their breakage behaviour or fibre morphology, do not lead to any health-relevant release of fibre dusts.
- FRILO Software GmbH and RIB Software GmbH have stored key data for construction work with non-metallic reinforcement as standard in their well-known dimensioning software.

### Training

-

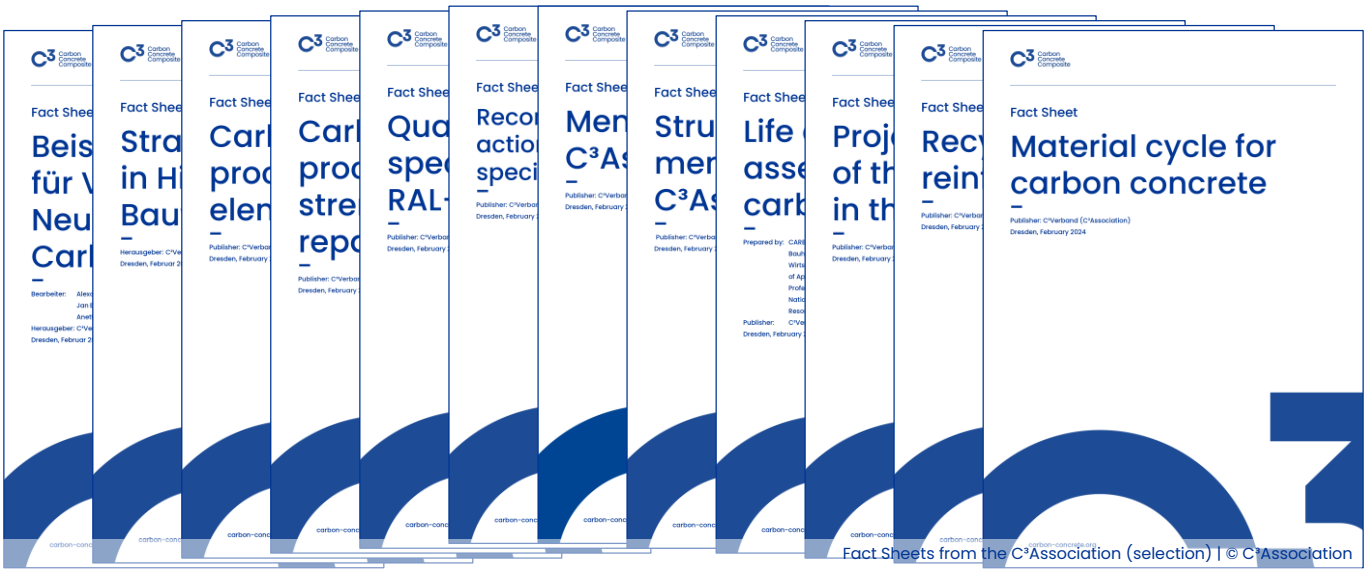
In accordance with the general requirements on the building and construction industry, work with carbon concrete requires qualified personnel. Educational institutions, clubs and associations as well as economical institutions are already conveying the latest technical standard and latest developments both to career starters and long-term professionals in suitable formats such as

- webinars and trainings provided by the C³Association,
- further education options and series of seminars through members of the C³Association,
- lectures and seminars at numerous colleges/universities of applied science.

### Further development

-

The C³Association and its members are taking on the responsibility of gradually making the building and construction industry even more positive. With the objective of establishing the members of




Fact Sheets from the C³Association (selection) | © C³Association

**Contact**
**C³ — Carbon Concrete Composite e. V.**
WTC Dresden, Ammonstraße 72 | 01067 Dresden, Germany
carbon-concrete.org • info@carbon-concrete.org • +49 351 48 45 67 00

**Dr.-Ing. Stefan Minar**
s.minar@carbon-concrete.org • +49 351 48 45 67 19

the C³Association as the main suppliers of carbon concrete construction technology,

- new material cycle projects, in particular on the subject of recycling (project WIRreFa | WIR! recyceln Fasern), standardisation (project ISC | Industry Standards Carbon Concrete), the use of more ecological concretes with a lower cement content or for the identification of new fields of application with special requirements in terms of humidity and alkalinity are being initiated, coordinated and controlled.
- position papers on the subject of climate-neutral construction are being prepared for the political and administration level and platforms organised for specialist exchange.
- promising interfaces are being built up to non-branch-specific developments, such as the production of carbon on the basis of the renewable resource lignin (wood waste product from paper production), the extraction of $CO_2$ from the air, the production from polyethylene or by generating algae biomass rich in lipids.

**Further literature**

-

Curbach M., Hegger J., Schladitz F., Tietze M., Lieboldt M.: Handbuch Carbonbeton. Einsatz nichtmetallsicher Bewehrung. 2023. 595 S.

RAL Deutsches Institut für Gütesicherung und Kennzeichnung e. V.: Verhinderung von Gefährdungen durch biobeständige, lungengängige Faserstäube bei der Carbonbetonbauweise. Güte- und Prüfbestimmungen. RAL-RG 351. 2021. 5 S.

Tagungsbänder zu den Carbon- und Textilbetontagen (https://www.carbon-textilbetontage.de/tagungsband)

Fachartikel in den renommierten Zeitschriften zum Bauwesen, wie Bauingenieur, Beton- und Stahlbetonbau, BWI – BetonWerk International etc.

**Related links**

-

https://carbon-concrete.org/carbonbeton/download

https://www.dibt.de/de/Service/Service-Suche.html

https://www.din.de/de/wdc-beuth:din21:362887890

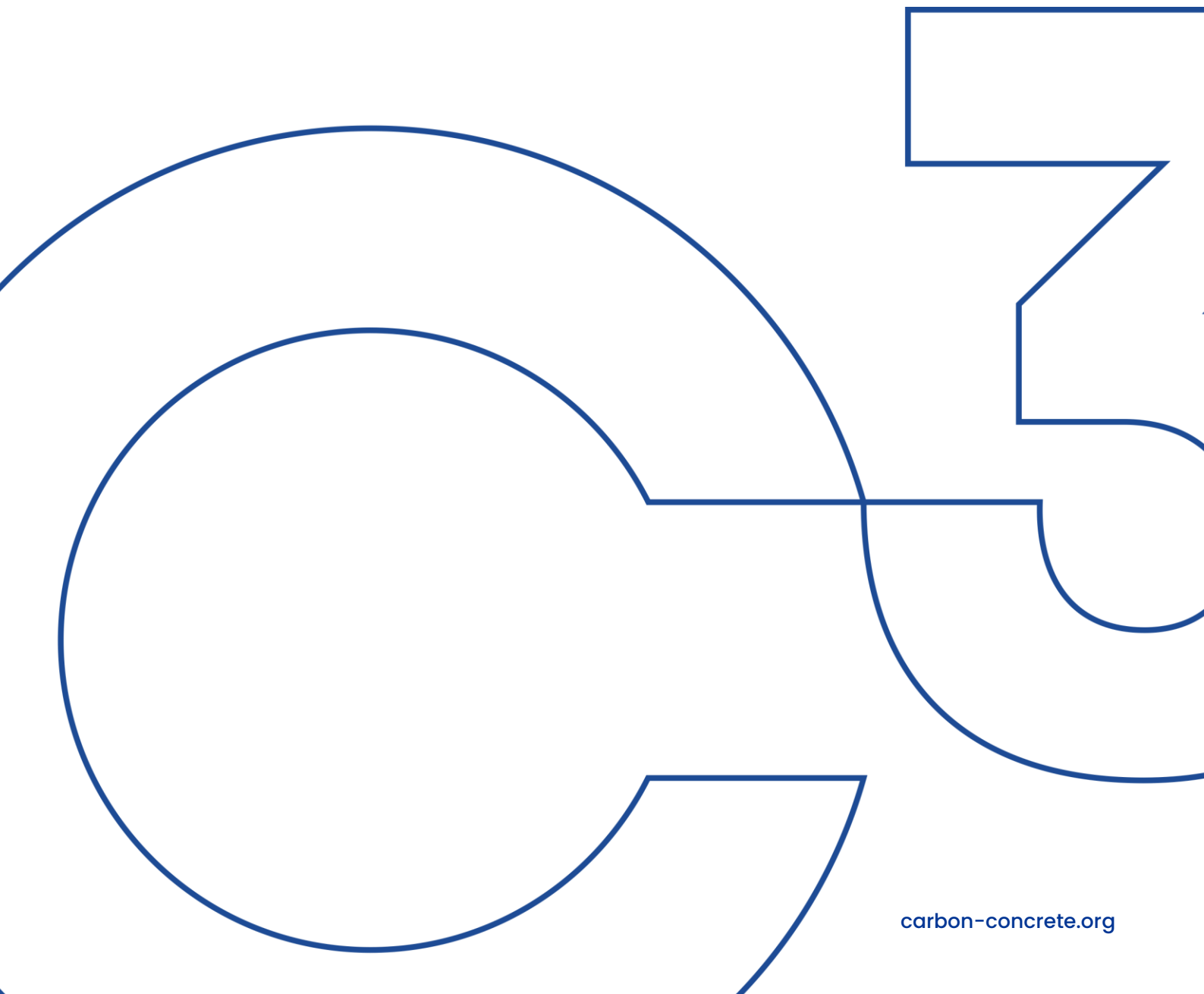
https://www.frilo.eu

https://www.rib-software.com/home

Use of carbon concrete for new builds (CUBE in Dresden) | © S. Gröschel, TU Dresden IMB

**Contact**
**C³ — Carbon Concrete Composite e. V.**
WTC Dresden, Ammonstraße 72 | 01067 Dresden, Germany
carbon-concrete.org • info@carbon-concrete.org • +49 351 48 45 67 00

**Dr.-Ing. Stefan Minar**
s.minar@carbon-concrete.org • +49 351 48 45 67 19



carbon-concrete.org