fischer

Installation Manual.

C-Fiber Force Strengthening System
with Carbon Fiber Fabrics.

Safety Instructions
Please read the Safety Data Sheets (SDS) and Technical Data Sheets (TDS) before using the products! When working with chemical products, use suitable protective clothing, protective gloves and safety glasses. IMPORTANT: Please follow the application instructions, which are included in every package.

 These application instructions were created with care. However, fischerwerke GmbH & Co.KG does not take over any liability for any errors in these application instructions and their consequences. There is also no liability for direct or consequential damage taken from incorrect use of the products.

Performance of construction materials (Epoxy resins) vary with external conditions (e.g. project site conditions such as temperature or humidity).

The suitability of the strengthening kit must be checked and confirmed by the responsible planer. All product names and brand names used belong to the owner, even if not explicitly marked as such. The content is subject to changes.

Content

1 Introduction

This installation manual describes the safe use of fischer FRS-W U300 and FRS-W U600 carbon fiber (CF) Fabrics. This document must be used or referred to in conjunction with all relevant Technical Data Sheets (TDS), Safety Data Sheets (SDS), Technical Assessments and project specifications. Structural strengthening works shall only be carried out by experienced and trained specialists. For professional product trainings and in case of any questions about our design software REINFORCE-FIX©, please consult the technical team of the national fischer subsidiaries. Note that the inadequate choice on the strengthening or retrofitting method, incorrect structural design, inadequate installation might cause significant risks.

2 System description

2.1 Intended use

The primary intended use of the fischer C-Fiber Force Strengthening System with CF Fabrics is the strengthening of reinforced concrete or pre-stressed concrete structures. The fischer C-Fiber Force Strengthening System was developed for safety relevant applications. The design and application of CF Fabrics on base materials such as timber or masonry require engineering judgement.

The manufacturer strongly recommends the use of the fischer C-Fiber Force Strengthening System as a whole. Combined applications with products from other manufacturers are out of the responsibility range of the fischer group.

2.2 References

This installation manual was written in accordance with the recommendations of ACI 440.2R (2017) and the DAfStb Guideline (Strengthening of concrete members with adhesively bonded reinforcement, Part 3: Execution, 2012)

2.3 Restrictions

This product shall only be used for its intended purpose. Further design details or design information are to be found in the structural design, technical drawings, specifications and risk assessments of the corresponding design engineer or specialist contractor.

3 fischer C-Fiber Force Strengthening System

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The primary intended application scope of the fischer C-Fiber Force Strengthening System is to strengthen reinforced or pre-stressed concrete members. The FRS-W U300 and FRS-W U600 CF Fabrics are system components of the fischer C-Fiber Force Strengthening System.

Table 1: Constituents of the fischer C-Fiber Force Strengthening System with corresponding short product descriptions

Product name	Description
FRS-L-S & FRS-L-H FRS-L-S NSM	Pultruded, precured carbon fiber reinforced polymer (CFRP) Laminates for the structural strengthening
FRS-CS	Thixotrophic, 2-component epoxy mortar for the installation of CFRP Laminates and steel plates
FRS-W U300 FRS-W U600	Unidirectional Carbon Fiber Fabrics with 300 g/m² or 600 g/m² area density
FRS-FC	Unidirectional open end high-strength carbon fiber anchor for optimal end-anchorage of Carbon Fiber Fabrics
FRS-CF	Thixotropic, 2-component epoxy-based saturating resin for the application of FRS-W and FRS-FC
FRS-PC 11	Thixotropic, high-viscosity, low-shrinkage, 3-component epoxy-based concrete repair mortar for reprofiling, surface levelling and for increasing or restoring concrete cover
FRS-BA	2-component, epoxy-based, solvent-free high performance bonding agent for optimal adhesion between different concrete repair mortars and existing concrete as well as corrosion protection for embedded steel reinforcing bars
FRS-CP red FRS-CP grey	Low viscosity, 2-component, epoxy-based corrosion protection primer for exposed steel surfaces as well as embedded steel rebars in two colour versions, red and grey
FRS-SF	Highly UV resistant and water repellent, waterborne protective coating with high durability against environmental exposure for CFRP reinforcement in outdoor applications.
FRS-FP	Waterborne, intumescent coating for CFRP strengthening systems against fire and smoke development
FRS-CA	Universal cleaning agent for the FRS-L-S, FRS-L-H, FRS-L-S NSM CFRP Laminate and tools

4 Certification and technical assessments

The intended use of the fischer C-Fiber Force Strengthening System using CF Fabrics is regulated by:

- ICC-ES Evaluation Report (ESR-4774)

5 Storage conditions

The materials shall be stored in closed and undamaged original packaging in a dry environment at ambient temperature. Please note the minimum and maximum storage temperature and the shelf life in the corresponding product data sheets (TDS) and product labels.

The FRS-W U300 and FRS-W U600 CF Fabrics shall only be transported in the original packaging or with other adequate protection against mechanical and chemical damage.

6 Recommended equipment

6.1 Equipment, devices, tools and accessories

For the adequate installation of the fischer C-Fiber Force Strengthening System, it is recommended to have the following equipment on site for proper installation:

- Humidity meter
- Equipment for measuring the moisture content of components e.g. concrete moisture meter (CMM)
- Thermometer for air and surface temperatures
- Crack width ruler
- Concrete surface tester to determine the surface unevenness
- Concrete pull-off tester including steel disks with a diameter of 50 mm disc to determine the concrete tensile strength, adequate adhesive for installation
- Diamond core drilling machine and accessories (for concrete pull-off tests)
- Concrete scanner to determine concrete cover and / or position and/or diameter of rebars
- Weighing scale with suitable weight range and precision
- Equipment for substrate preparation (by caulking, blasting, grinding and for cleaning work)
- Handheld agitator suitable for mixing the chemical products, with a rotation speed (≤ 300 rpm)
- Application equipment
  (Trowel, spatula, steel brushes, adhesive application device, cleaning cloth, etc.)
- Ruler and visible marker
- Wet film thickness gauge

6.2 Cleaning of tools and accessories

All tools and processing accessories must be cleaned immediately after use with FRS-CA Cleaning Agent or another suitable solvent. Cured materials can only be removed mechanically.

7 Health and safety

7.1 Risk assessment

All health and safety risks must be assessed and adequate countermeasures shall be defined. This includes the very condition of the structure and the resulting risks thereof, the processing of all materials used on site as well as working methods.

All work and working procedures must be carried out in full compliance with the relevant local safety and environmental regulations in force on site.

7.2 Personal safety

During the installation, safety shoes, safety gloves and other suitable skin protection must be always worn. It is strongly recommended to use adequate disposable safety equipment during the processing and application of the materials. Since epoxy adhesives or saturating resins can cause skin irritation, always wear protective gloves e.g. nitrile-based hand gloves when working with them. Unprotected skin must always be covered with protective cream before starting work.

Always wear suitable eye protection during processing, mixing and installation of the products. It is recommended to carry eye wash with you at all times. Always wash hands with suitable soap and clean water after processing the materials.

The work area must be well ventilated and workers should take regular breaks in the fresh air, to avoid health problems. The developing dust and quartz sand during drilling, grinding or sandblasting the concrete can be hazardous. Avoid the inhalation of concrete of CFRP dust. To protect yourself and others, use e.g. vacuum cleaner or other adequate suction techniques. Always wear a dust mask or respirator when grinding concrete or cutting the CFRP Laminate. For detailed health and safety information, see the relevant Safety Data Sheets (SDS).

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7.3 First aid

If the epoxy mortar-based chemicals come into contact with the eyes or mucous membranes, the contact lenses must be removed and the eyes must be rinsed immediately with clean, warm water for 10–15 min. and a medical doctor should be consulted

If chemicals come into contact with the skin, it must be cleaned immediately and carefully rinsed with clean warm water.

In case an accident happens, despite all the preventive measures, the corresponding SDS must be immediately handed over to the emergency services. This helps the emergency services to select the appropriate medical treatment(s). For detailed health and safety information, refer to the relevant Safety Data Sheet (SDS) of the individual products.

7.4 Waste disposal

Excess materials must not be poured down in drains or into water supplies. Waste and packaging must be disposed by specialized waste management companies or partners in accordance with local legislation and official requirements. Furthermore, chemical materials must not be allowed to enter the soil, watercourses, drains or sewers. Chemical waste in uncured form or leaking adhesive must be disposed as hazardous waste.

Waste in the form of cured adhesive can be safely disposed off as normal construction waste in accordance with local legislation. For detailed environmental and safety information, refer to the relevant Safety Data Sheet (SDS).

8 Installation steps

8.1 Preparation works, substrate and environmental conditions

Requirements and preparation

Environmental conditions

- Verify the residual moisture content of the concrete using an adequate device (e.g. CCM)
- The residual moisture content of the concrete shall not exceed max. 4 % by weight of concrete grade C30/37 and 3 % by weight for concrete grade C35/45, measured with a CM device in accordance with ACI 503.4.
- The residual moisture content of the concrete shall not exceed max. 4 % by weight according to the DAfStb Guidelines (Strengthening of concrete members with adhesively bonded reinforcement, Part 3: Execution).
- Verify the permitted temperature range of the member with a thermometer.
- Verify that the chemicals are stored at the permitted storage temperature before use.
- Underground temperature of the member to be strengthened should be higher than +10 °C and at least 3 K above dew point during and after application throughout the curing time.
- The maximum temperature should not exceed 40 °C and the relative humidity should be below 75 %. Check the humidity with an adequate humidity measurement device.

Requirements and preparation

Concrete substrate conditions

Concrete patching / Concrete Reprofiling / crack injection / corrosion inhibition works on the substrate may be necessary prior to the application of the CF Fabrics if[1]:

- There are visible defects in the concrete, such as concrete spalling, or unevenness exceeding 3 mm void depth. The unevenness of the concrete surface shall be verified by concrete surface tester.
- There is insufficient concrete cover. The concrete cover of the internal reinforcement shall comply with the valid design standard but at minimum shall be 10 mm. The concrete cover thickness shall be verified by a concrete scanner device. If the concrete cover is insufficient it should be elevated by application repair mortar, concrete or shotcrete.
- There are cracks of more than 0.01 inch (0.25 mm) present[2]. Crack sizes can be measured with a crack width ruler. Care should be taken to seal cracks that may cause infiltration of water.[3]
- When active corrosion of reinforcement rebars is present.

If these conditions are not fulfilled, the thickness of the concrete cover shall be increased by adequate means, methods and materials. Further instructions on the adequate concrete patching can be found in e.g. DAfStb Guideline (Strengthening of concrete members with adhesively bonded reinforcement, Part 3: Execution, 2012); ACI 546R, ICRI 310.2R, DAfStb TR. Information on treatment of cracks can be found in ACI 224.1R. Information for corrosion inhibition can find in the norm DIN EN 1504-9 principles 7-11.

The concrete surface needs to be dry, oil, dust-free and free of any chemically separating substances.

[1] It's essential to have an intact substrate without damaged or deteriorating concrete prior to installation of FRS-W U300 and FRS-W U600 CF Fabrics. The FRS-W U300 and FRS-W U600 CF Fabrics require an unimpeded bond to the substrate.

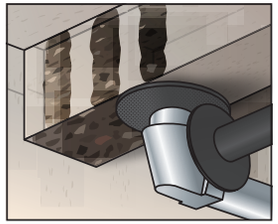
[2] Cracks > 0.254 mm (10 mils) are an indicator for movements in the structure that may affect the durability of the strengthening system (ACI 224.1R).

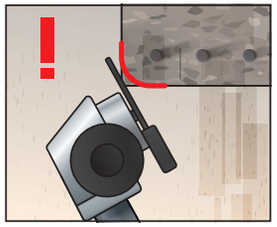
[3] Permanent moisture may affect the durability of the strengthening systems.

8.2 Installation of the CF Fabrics on concrete surface

Dry layup installation technique is especially suitable for FRS-W U300 with an area density of 300 g/m². Wet layup installation technique is also suitable for FRS-W U300 but preferentially used for FRS-W U600 with a higher area density of 600 g/m².

Surface preparation





The concrete surface, where the strengthening products will be applied must be roughened up by means of one the following techniques:

- Compressed air blasting with solid abrasives
- Shot peening
- Processing with a needle pistol
- Grinding (see figure)
- High-pressure water blasting

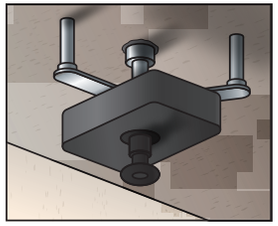
The sharp concrete edges must be rounded to corner radius of > 13 mm according to ACI 440.2R.

If the structural design and execution are followed by DAfStb Guideline, the corner radius should be > 25 mm.

External and internal corners can be built up with a suitable repair mortar to achieve the corner radius. After the surface pretreatment, the coarse aggregates (≥ 4 mm) must be visible on the concrete surface. The roughened concrete surface enables the penetration of epoxy into the substrate and ensures proper adhesion. The remaining loose concrete parts as well as dust must be removed.

Care shall be taken of the national work safety regulations. The cleaned concrete surface should be protected until the CF Fabrics application.

Surface testing



Prior to application of the CF Fabrics, the suitability of the concrete surface must be verified through concrete pull-off tests. The concrete surface tensile strength is to be determined using a concrete pull-off device. If concrete repair works were performed, the surface tensile strength has to be determined on the reprofiled concrete surface.

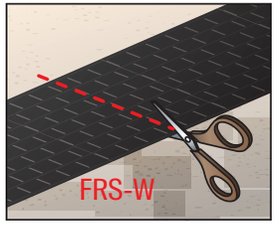
The concrete surface tensile strength should be measured according to ASTM C1583/C1583 M after surface preparation or according to EN 1542.

At least five tests in different locations have to be performed. The choice on the number and position of the pull-off tests is the responsibility of the design engineer.

The characteristic mean concrete surface tensile strength must be at least ≥ 1.0 N/mm² according to DAfStb Guideline (Strengthening of concrete members with adhesively bonded reinforcement, Part 3: Execution, 2012) or ≥ 1.4 N/mm² according to ACI 440.2R (2017). If higher values are used in the structural design, these values have to be verified by concrete pull-off tests.

In case the requirement on the minimum concrete surface tensile strength is not met, the decision on the adequacy of the strengthening method with CF Fabrics is the responsibility of an experienced structural engineer. The detailed procedure of the surface testing procedure is described in a separate manual.

CF Fabrics preparation



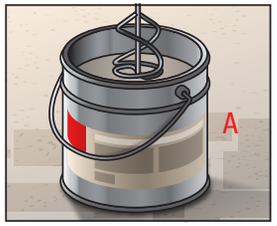
The Carbon Fiber Fabrics FRS-W U300 & FRS-W U600 shall be completely dry, free of oil and dust and the surface on the entire length must be checked for visible damage such as undulations.

In case of any damage observed, the wrap should not be used.

Cut the CF Fabrics with a technical scissor or similar tool to the desired length and take care to make a clean and linear cut.

Don't fold the CF Fabrics orthogonal to the fiber direction to prevent damage of the carbon fiber rovings. A sufficient bending radius is required to avoid any damage of the fibres. However, careful folding parallel to the main fiber direction is allowed and will not comprise the tensile strength of the CF Fabrics.

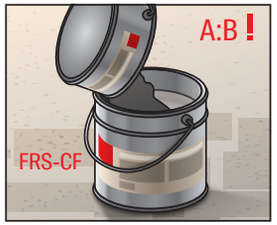
Preparation of saturating resin and CF Fabrics installation



The FRS-CF 2-component epoxy saturating resin must be prepared by following the processing steps in accordance with the Technical Data Sheet (TDS) of FRS-CF. Note the required mixing ratio, pot life, storage temperature and the proper mixing procedure.

Special care should be taken of the work safety while working with fischer FRS-CF.

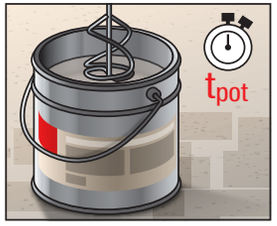
If phase separation is observed after opening the can components, the individual can components should be homogenized by stirring them separately, before mixing them. This is especially recommended when partial quantities are taken.



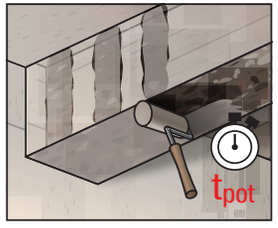
Add component B to component A and mix it (handheld agitator) for 3 minutes with 300 rpm without air bubbles until a homogeneous and uniform gray tone is achieved.

If partial quantities are taken, please pay attention on the correct mixing ratio by weight of component A and component B (3:1). Using weighing scale is recommended for adhere the mixing ratio.

The intended use of FRS-CF is within the temperature range from 10 °C to 40 °C.



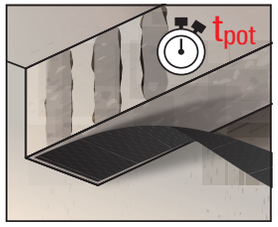
The pot life (working time) is 45 minutes at 23 °C and it's depending on environment temperature. Precooled material and smaller quantities can help to prolong the pot life.



The saturating resin FRS-CF is applied with a roller on the concrete substrate. Take care to adjust the consumption of FRS-CF to the roughness of the surface.

In the first working step, a layer FRS-CF shall be applied on the concrete surface with a consumption of 0.80–1.00 kg/m².

Take care to completely coat the concrete surface with FRS-CF, where later CF Fabrics will be applied. The actual consumption rate might be dependent on the surface roughness and cavities



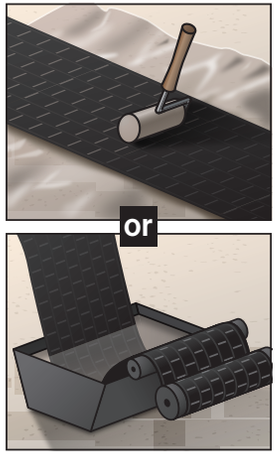
Dry layup installation technique (Recommended for FRS-W U300)

The dry CF Fabrics FRS-W is pressed into the previously applied saturating resin. By using a roller, the CF Fabric needs to be completely impregnated by the FRS-CF, without dry spots and air inclusions.

Work in fiber direction at all times.

In case of using multiple CF Fabric layers, an additional amount of 0.5–0.75 kg/m² FRS-CF is to be applied per each new CF Fabrics layer.

After exceeding the pot-life of FRS-CF, the material must not be used.



Wet layup installation technique (Recommended for FRS-W U600)

The wet layup installation technique means, that the CF Fabrics need to be pre-impregnated before it is pressed against the concrete surface and placed in the previously applied FRS-CF.

The pre-impregnation is possible in manual resin application or by using an impregnation machine (see on the left).

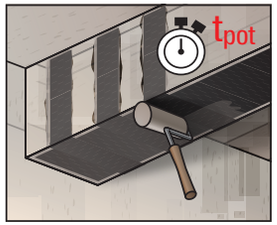
For manual resin application spread the saturating resin FRS-CF on a PE foil and place the CF Fabrics into the resin. Spread a further amount of the saturating resin on the CF Fabric. Impregnate the CF Fabric with a roller and remove the excess resin.

For application with an impregnation machine or device, please check the compatibility with the FRS-CF saturating resin to ensure complete impregnation of the CF Fabric.

Apply the pre-impregnated "wet" CF Fabrics to the previously coated concrete substrate and remove air inclusions by using a roller. Ensure that the CF Fabrics is completely impregnated with FRS-CF.

In case of using multiple CF Fabric layers, an additional amount of 0.5–0.75 kg/m² FRS-CF is to be applied per each new CF Fabric layer.

After exceeding the pot-life of FRS-CF, the material must not be used.

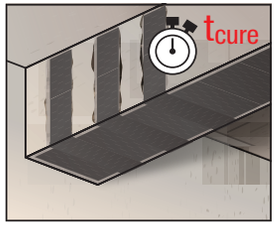


After the last CF Fabric layer, the last layer should be coated with 0.5–0.7 kg/m² FRS-CF.

In case of multiple CF Fabric layers, every additional layer must be applied within the pot life of the saturating resin. If the application of additional layers needs to be performed after exceeding the pot life, application of further layers should only be done after the curing of the last layer applied.

If an overlap of CF Fabrics is foreseen in the structural design, the CF Fabrics must be applied in the main fiber direction. The overlap must be at least 150 mm, in case of axial confinement of columns at least 250 mm if the structural design was based on the DAFSTB guideline “Strengthening of concrete members with bonded reinforcement” (2012).

The number and layout of CF Fabrics used needs to be calculated by an experienced engineer. Application of multiple layers of CF Fabrics is permitted according to the DAfStb guideline “Strengthening of concrete members with bonded reinforcement” (2012) up to 5 layers to flexural strengthening and 10 layers for axial confinement, and according to ACI440.2R (2017) in conjunction with the ICC-ES Evaluation Report (ESR-4774).



The CF Fabrics does not require additional supportive temporary fixing solutions during the curing process.

The live loads on the structure are allowed after 48 h curing at 20 °C. Lower temperatures result in longer curing time. The applied the CF Fabrics should be protected against mechanical and chemical damage, shock, vibration, movements, etc. during the hardening time. If additional protective coating is applied, the uncured adhesive should be sprinkled with sand to improve the adhesion and excess sand has to be removed after curing. Prior to application of further coating systems, the FRS-CF shall be fully cured.

The strength development of the different material parameters as a function of the hardening time is given in the Technical Data Sheet (TDS) of FRS-CF.

In case of exposure other than classes X0, XC1 and XC3 according to DIN EN 1992-1-1 of CF Fabrics a protective coating (FRS-SF) is required to prevent aging due to UV-radiation or permanent moisture.

Inspection and Quality control after the installation

After the saturating resin FRS-CF has cured, the bonded surface is checked for voids by carefully tapping it or by means of pulse thermography or an equivalent method.

To verify the adhesion of the CF Fabrics to the concrete substrate at least 5 pull-off tests according to EN 1542 or according to ASTM C1583/C1583 M should be performed on a reference CF Fabrics, which was placed in a representative location. It is strongly recommended to apply a reference CF Fabrics piece during the course of the applications works.

The minimum requirement on the characteristic mean surface tensile strength is ≥ 1.0 N/mm² according to DAfStb Guideline (Strengthening of concrete members with adhesively bonded reinforcement, Part 3: Execution, 2012) or ≥ 1.4 N/mm² according to ACI 440.2R (2017) and the failure should occur in the concrete layer (concrete cohesion failure) and not at the CFRP Laminate-concrete interface. If a higher value was used in the structural design this value must be verified.

The concept of the quality inspection plan of the strengthened structure or structural member is the duty of the responsible structural engineer, following the national and international regulations, such as AC 178, DAfStb Guideline [2].

8.3 Installation of the CF Fabrics on masonry and timber

In addition to reinforced concrete, the fischer FRS-W U300 and FRS-W U600 CF Fabric can also be applied on timber and masonry. Ensure that the masonry structure is suitable for the installation of the fischer FRS-W U300 and FRS-W U600 CF Fabric. The system can be installed on moderately cracked surface, whereas crumbling bricks and poor substrate quality will compromise the quality and effectiveness of the strengthening system. The responsible specialist engineer must carry out the necessary inspection and calculations, eventually pull-off tests on site to verify the assumptions met during the structural design. Your national fischer subsidiary provides you with consultancy if required. For installation, remove dust completely with oil-free compressed air or vacuum and remove loose masonry parts.

9 Legal notes

The above information, in particular the suggestions for processing and use of our products, are based on our knowledge and experience under normal conditions, provided the products have been stored and used properly. Due to the different materials, substrates and deviating working conditions, a guarantee of a work result or liability, from whatever legal relationship, can neither be justified from these instructions nor from verbal advice, unless we are charged with intent or gross negligence in this respect. In this context, the user must prove that he has in writing all knowledge required for a proper and reasonable assessment by fischer, has been communicated to fischer thoroughly and on time. The user must test the products regarding their suitability for the intended use.

The product specifications are subject to change without notice. Third party property rights must be observed. In all other respects, our respective terms and conditions of sale and delivery apply. Always the latest product data sheet (TDS) applies, which should be requested from us.

10 References

[1] ACI 440.2R-17 “Guide for the Design and Construction of Externally Bonded FRP Systems for Strengthening Concrete Structures”, ACI Committee 440, American Concrete Institute, Farmington Hills, United States of America, **2017**.

[2] DAfStb-Guideline “Strengthening of concrete members with adhesively bonded reinforcement”, W. Finckh, A. Ignatiadis, R. Niedermeier, U. Wiens, K. Zilch, Deutscher Ausschuss für Stahlbeton e. V. – DAfStb, Berlin, Germany, **2012**.

[3] ESR-4774 according to AC125 Acceptance Criteria for Concrete and Reinforced and Unreinforced Masonry Strengthening using Externally Bonded Fiber-Reinforced Polymer (FRP) Composite Systems, ICC Evaluation Service, Brea, United States of America, **2024**.

[4] ACI PRC-546-14 “Guide to Concrete Repair”, ACI Committee 546, American Concrete Institute, Farmington Hills, United States of America, **2014**.

[5] ICRI 310.2R-2013 “Selecting and Specifying Concrete Surface Preparation for Sealers, Coatings, Polymer Overlays, and Concrete Repair”, International Concrete Repair Institute, Inc., Minnesota, United States of America, **2013**.

[6] ACI 224.1R-07 “Causes, Evaluation, and Repair of Cracks in Concrete Structures”, ACI Committee 224, American Concrete Institute, Farmington Hills, United States of America, **2007**.

[7] EN 1504-9:2008 “Products and systems for the protection and repair of concrete structures – Definitions, requirements, quality control and evaluation of conformity – Part 9: General principles for the use of products and systems”, European Committee for Standardization, Brussels, Belgium, **2008**.

[8] EN 206:2013+A2:2021 „Concrete – Specification, performance, production and conformity“, European Committee for Standardization, Brussels, Belgium, **2013**.

[9] DIN 1045-1:2023-08 “Concrete Structures – Part 1: Planning and design”, Deutsches Institut für Normung e. V., Berlin, Germany, **2023**.

[10] EN 14487-1:2022 “Sprayed concrete - Part 1: Definitions, specifications and conformity, European Committee for Standardization”, Brussels, Belgium, **2022**.

[11] DIN 18551:2014-08 “Sprayed concrete - National application rules for series DIN EN 14487 and rules for design of sprayed concrete constructions”, Deutsches Institut für Normung e. V., Berlin, Germany, **2014**.

fischer stands for

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