Deutsches Institut für Bautechnik

Public-law institution jointly founded by the federal states and the Federation

European Technical Assessment Body for construction products

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European Technical Assessment ETA-24/0281 of 17 March 2026

English translation prepared by DIBt - Original version in German language

General Part

Technical Assessment Body issuing the European Technical Assessment:	Deutsches Institut für Bautechnik
Trade name of the construction product	fischer C-Fiber Force Strengthening System
Product family to which the construction product belongs	Kits for the strengthening of concrete elements by externally bonded and near surface mounted CFRP strips
Manufacturer	fischerwerke GmbH & Co. KG Klaus-Fischer-Straße 1 72178 Waldachtal DEUTSCHLAND
Manufacturing plant	fischerwerke
This European Technical Assessment contains	51 pages including 45 annexes which form an integral part of this assessment
This European Technical Assessment is issued in accordance with Article 95(4) of Regulation (EU) 2024/3110, on the basis of	EAD 160086-01-0301
This version replaces	ETA-24/0281 issued on 6 December 2024

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Specific part

1 Technical description of the product

Subject matter of regulation of this European Technical Assessment (ETA) is the "fischer C-Fiber Force Strengthening System" for the strengthening of concrete elements by externally bonded (EB) CFRP strips and near surface mounted (NSM) CFRP strips (in the following referred to as kit). The kit is used for the strengthening of concrete elements by bonded reinforcements to increase the flexural capacity of the elements either to compensate for design deficiencies, execution flaws and aging induced loss of capacity of the existing structure or increase of capacity in case of increased loads or repurposing of the existing structure. The kit for the strengthening of concrete elements by externally bonded or near surface mounted carbon fiber reinforced polymer strips consists of the following components:

A Two types of unidirectional carbon fiber reinforced polymer (CFRP) strips for EB:
- FRS-L-H and FRS-L-S,

One type of unidirectional carbon fiber reinforced polymer (CFRP) strips for NSM:
- FRS-L-S NSM (same type of strips as FRS-L-S for EB)

B Structural bonding agent for CFRP strips FRS-CS acc. to EN 1504-4:2004, EN 1504-3:2005, EN 1504-6:2006, for the installation of FRS-L-S, FRS-L-S NSM, and FRS-L-H CFRP strips,

C Repair mortar with polymer binder FRS-PC 11 acc. to EN 1504-3:2005,

D Bonding agent for the repair mortar FRS-BA acc. to EN 1504-7:2006,

E Cleaning agent for the CFRP strips FRS-CA.

Furthermore, the manufacturer recommends the coating FRS-SF in case of exposure scenarios with increased UV-exposure as mentioned in the manufacturers product installation manual (MPII) and national regulations which is not covered by the scope of this ETA.

The following information on the kit and its components are given in the annexes to this ETA:

An overview of the kit and its components is given in annex A1 – A3 and its installed condition in annex A4 and A5.

A detailed description of the components of the kit is given in:
- Annex C9 for the CFRP strips (comp. A),
- Annex C1 for the structural bonding agent FRS-CS (comp. B),
- Annex C3 for the repair mortar FRS PC 11 (comp. C),
- Annex C18 for the bonding agent of the repair mortar FRS-BA (comp. D),

- The description of the intended use, design, installation of the kit and curing conditions of the structural bonding agent, repair mortar and bonding agent for the repair mortar is given in annex B1 and B2.
- Instruction of strengthening of concrete structures with externally bonded CFRP strips and near surface mounted CFRP strips is given annex B3 – B6.

- The results of the essential characteristics from assessment procedures according to EAD 160086-01-0301 are given in annex C:
  - Annex C10 – C17 for the CFRP strips (comp. A),
  - Annex C2, C5 and C6 for the structural bonding agent FRS-CS (comp. B),
  - Annex C4, C7 and C8 for the repair mortar FRS PC 11 (comp. C),
- The essential characteristics of the system resulting of from the assessment procedures according to EAD 160086-01-0301 are given in annex C19 – C34.

2 Specification of the intended use in accordance with the applicable European Assessment Document

The kit is used for strengthening the tensile area of concrete elements like beams, slabs, walls and columns. It is intended to contribute to the increase of the structural capacity for static and quasi-static as well as dynamic loaded concrete elements according to the design rules. The kit covers two different types of strengthening methods, as depicted in annex A4 and A5, in which CFRP strips are either applied externally onto the prepared concrete surface (EB) or in milled slots perpendicular to the concrete surface (NSM) in accordance with the manufacturer´s product installation instructions (MPII).

In case the surface conditions required are not fulfilled due to defects and damages of the concrete element the repair mortar (components C and D), normal concrete or shotcrete (both not part of the kit) may be used to improve the concrete surface condition prior to the application of the CFRP strips to the repaired concrete surface in accordance with the MPII and national regulations.

The performances given in section 3 and annex C are only valid if the kit is used in compliance with the specifications and conditions given in annex B and the MPII. Irrespective of annex B and the MPII, national regulations need to be respected.

The verifications and assessment methods on which this ETA is based lead to the assumption of a working life of the kit of at least 25 years when installed, provided that the kit is subject to appropriate installation and use. These provisions are based upon the current state of the art and the available knowledge and experience. The indications given as to the working life of the construction product cannot be interpreted as a guarantee neither given by the product manufacturer nor by the Technical Assessment Body issuing this ETA but are regarded only as a means for expressing the expected economically reasonable working life of the construction product.

3 Performance of the product and references to the methods used for its assessment

3.1 Mechanical resistance and stability (BWR 1)

No.	Essential characteristic	Assessment method according to EAD 160086-01-0301	Performance
1	Glass transition temperature of the structural bonding agent FRS-CS	2.2.1	See Annex C2
2	Glass transition temperature of the repair mortar FRS-PC 11	2.2.1	See Annex C4
3	Flexural and compressive strength of the structural bonding agent FRS-CS	2.2.2	See Annex C5 and C6
4	Flexural and compressive strength of the repair mortar FRS-PC 11	2.2.2	See Annex C7 and C8
5	Flexural and compressive strength of the structural bonding agent FRS-CS, cured at minimum temperature of installation in depending on the curing time	2.2.3	See Annex C5 and C6
6	Flexural and compressive strength of the repair mortar FRS-PC 11, cured at minimum temperature of installation in depending on the curing time	2.2.3	See Annex C7 and C8
7	Modulus of elasticity, tensile strength and strain at failure of CFRP strips	2.2.4	See Annex C10 and C11
8	Resistance of CFRP strips after storage in alkaline environment at maximum temperature according to the intended use	2.2.5	See Annex C12 to C15
9	Resistance of CFRP strips in alkaline environment under long-term load at maximum temperature according to the intended use	2.2.6	See Annex C16 and C17
10	Bond strength of specimens cured at standard environmental conditions	2.2.7	See Annex C19
11	Bond strength after low-cycle fatigue action	2.2.8	see Annex C20
12	Bond strength after long-term loading under harsh climatic conditions	2.2.9	See Annex C21
13	Bond strength of specimens cured at minimum temperature of installation depending on the curing time	2.2.10	See Annex C22
Further essential characteristics only of externally bonded (EB) CFRP strips			
14	Shear resistance of the anchorage of CFRP strips externally bonded to concrete	2.2.11	See Annex C23 to C31
15	Fatigue behaviour of the anchorage of CFRP strips externally bonded to concrete	2.2.12	See Annex C32

No.	Essential characteristic	Assessment method according to EAD 160086-01-0301	Performance
Further essential characteristics only of near surface mounted (NSM) CFRP strips			
16	Ultimate anchorage load of near surface mounted CFRP strips	2.2.13	See Annex C33
17	Long-term ultimate anchorage load	2.2.14	No performance assessed

3.2 Safety in case of fire (BWR 2)

No.	Essential characteristic	Assessment method according to EAD 160086-01-0301	Performance
18	Reaction to fire	2.2.15	See Annex C34

4 Assessment and verification of constancy of performance (AVCP) system applied, with reference to its legal base

In accordance with EAD 160086-01-0301 the applicable European legal act is: 2000/606/EC.
The system to be applied is: 1+

5 Technical details necessary for the implementation of the AVCP system, as provided for in the applicable EAD

Technical details necessary for the implementation of the AVCP system are laid down in the control plan deposited with Deutsches Institut für Bautechnik.

Issued in Berlin on 17 March 2026 by Deutsches Institut für Bautechnik

LBD Dipl.-Ing. Andreas Kummerow
Head of Department

authenticated:
Hering

Deutsches Institut für Bautechnik DIBt

Overview of the fischer C-Fiber Force Strengthening System – System components (part I)							
Components acc. to EAD	Comp. A			Comp. B	Comp. C	Comp. D	Comp. E
Product name	FRS-L-H CFRP strip	FRS-L-S CFRP strip	FRS-L-S NSM CFRP strip	FRS-CS Epoxy mortar	FRS-PC 11 Epoxy repair mortar	FRS-BA Bonding Agent	FRS-CA Cleaning Agent
Function	Unidirectional carbon fiber reinforced polymer (CFRP) strips			Structural bonding agent for CFRP strips	Repair mortar with polymer binder	Bonding agent for the repair mortar	Cleaning agent for the CFRP strips
Material	Precured composite from carbon fibers embedded in an epoxy matrix			Cold curing epoxy with mineral fillers	Cold curing epoxy with mineral fillers	Cold curing epoxy with mineral fillers	Solvent / Mixture of solvents
Type of application*	EB	EB	NSM	EB & NSM	EB & NSM	EB & NSM	EB & NSM
Packaging	100 m coil or 150 m coil**			5 kg can 10 kg can 585 ml injection cartridge	11 kg can	5 kg can	500 ml spray can
Shelf life	Infinite (if stored UV-protected)			36 months	36 months	36 months	36 months
Storage conditions	≤ 50 °C, dry environment and UV-protected			5 to 40 °C	5 to 40 °C	5 to 40 °C	5 to 30 °C
Application temp.	10 to 40 °C			10 to 40 °C	10 to 40 °C	10 to 40 °C	10 to 40 °C
Temp. range in use (after curing)	- 25 to 40 °C			- 25 to 40 °C	- 25 to 40 °C	- 25 to 40 °C	Not applicable

*EB: Externally bonded CFRP strips; NSM: Near surface mounted CFRP strips.
**Coil lengths for the different cross-section product variants are specified in the corresponding technical datasheets.

fischer C-Fiber Force Strengthening System	**Annex A1**
Product description System components and technical details	

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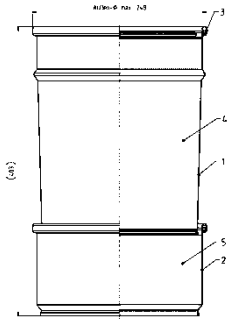
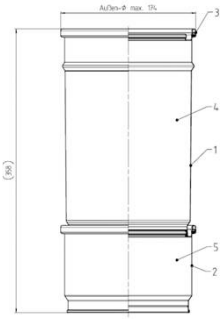
Overview of the fischer C-Fiber Force Strengthening System – System components (part II)

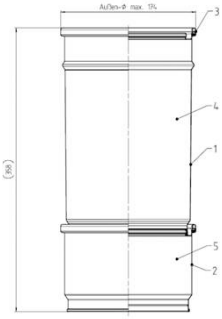
FRS-CS Epoxy Mortar (Comp. B, Structural Bonding Agent)

10 kg Can **5 kg Can**

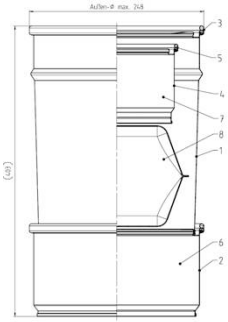




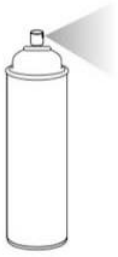
FRS-BA Bonding agent (Comp. D) **5 kg Can**



FRS-PC 11 Epoxy Repair mortar (Comp. C) **11 kg Can**



FRA-CA Cleaning agent (Comp. E) **500 ml Aerosol spray can**



Figures are not to scale

fischer C-Fiber Force Strengthening System	**Annex A2**
Product description System components and technical details	

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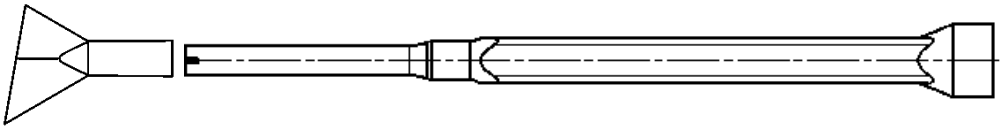
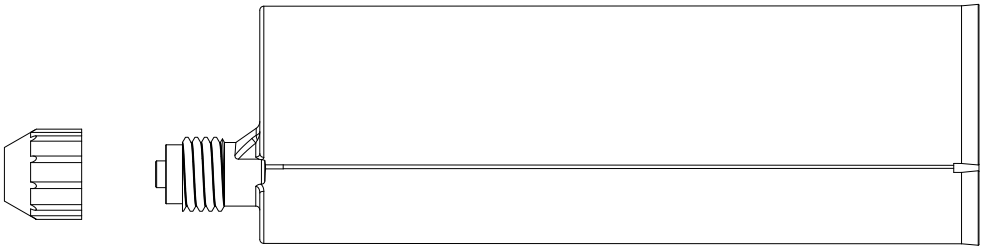
Overview of the fischer C-Fiber Force Strengthening System – System components (part III)

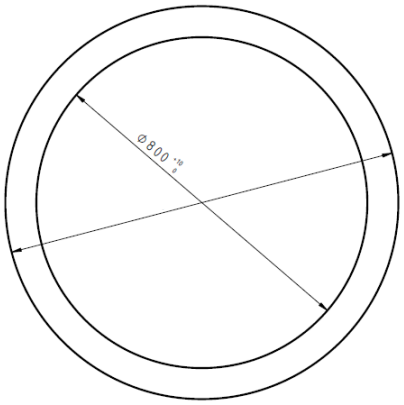
FIS UMR Static mixing nozzle for 585S cartridges with FRS-GA injection adapter



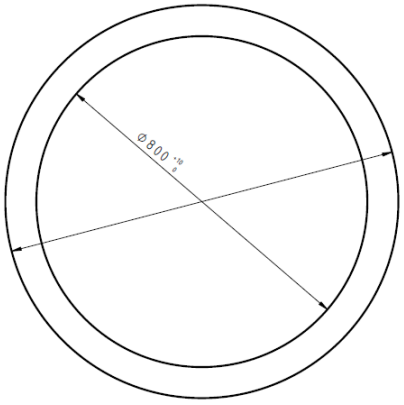
FRS-CS Epoxy Mortar 585 ml cartridges (Comp. B, Structural Bonding Agent)



FRS-L-S, FRS-L-H Externally bonded CFRP strips (Comp. A)



FRS-L-S-NSM Near surface mounted CFRP strips (Comp. A)



Figures are not to scale

fischer C-Fiber Force Strengthening System	**Annex A3**
Product description System components and technical details	

Overview of the fischer C-Fiber Force Strengthening System – strengthening techniques (part I)

Externally bonded CFRP strips

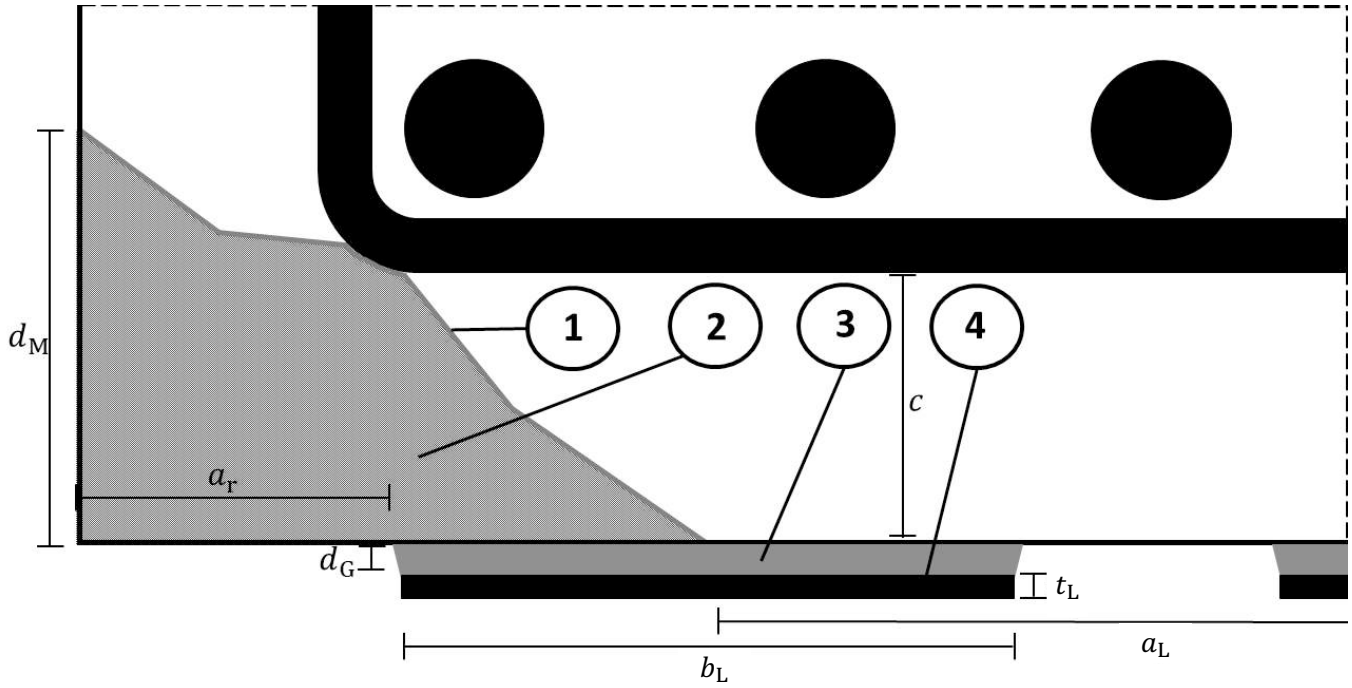


Figure A4.1: Strengthening layout with externally bonded FRS-L-S and FRS-L-H CFRP strips using the Epoxy Mortar FRS-CS with (optional) preceding concrete repair using the Epoxy Repair Mortar FRS-PC 11 with the Bonding Agent FRS-BA.

Legend

c	Concrete Cover of the internal reinforcement
a_r	Edge distance of the externally bonded reinforcements
a_L	Center to center distance of externally bonded CFRP strips
d_B	Layer thickness or consumption of the Bonding Agent FRS-BA
d_M	Layer thickness of the Epoxy Repair Mortar FRS-PC 11
d_G	Layer thickness of the structural bonding agent, the Epoxy Mortar FRS-CS
t_L	Thickness of the externally bonded CFRP strips
b_L	Width of the externally bonded CFRP strips

1	Component D - Bonding Agent FRS-BA:	Consumption d_D: 500 g/m² - 800 g/m²
2	Component C - Epoxy Repair Mortar FRS-PC 11:	Layer thickness d_M: 4 mm - 30 mm
3	Component B - Epoxy Mortar FRS-CS:	Layer thickness d_G: 1 mm - 5 mm
4	Component A - CFRP strip FRS-L-S / FRS-L-H:	thickness of CFRP strips t_L: 1,2 mm / 1,4 mm (≤ 2 layers)

Figures are not to scale

fischer C-Fiber Force Strengthening System	**Annex A4**
Product description Installed condition – externally bonded CFRP strips	

Overview of the fischer C-Fiber Force Strengthening System – strengthening techniques (part II)

Near surface mounted CFRP strips

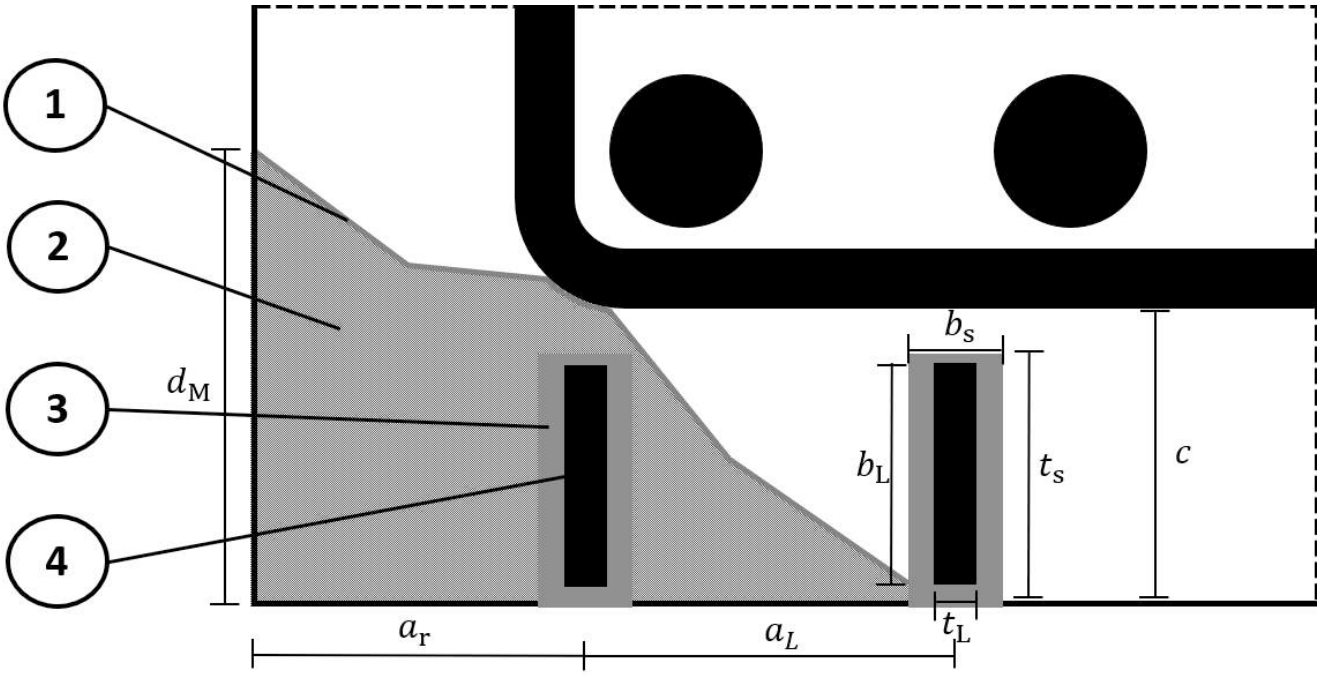


Figure A5.1: Strengthening layout with Near Surface Mounted FRS-L-S NSM CFRP strips using the Epoxy Mortar FRS-CS with preceding concrete repair using the Epoxy Repair Mortar FRS-PC 11 with the Bonding Agent FRS-BA.

Legend

c	Concrete cover of the internal reinforcements
a_r	Edge distance of the near surface mounted reinforcements
a_L	Center to center distance of the near surface mounted CFRP strips
d_B	Layer thickness or consumption of the Bonding Agent FRS-BA
d_M	Layer thickness of the Epoxy Repair Mortar FRS-PC 11
b_s	Width of the concrete slot $t_L + 1\ \text{mm} \leq b_s \leq t_L + 3\ \text{mm}$
t_s	Depth of the concrete slot $t_S \geq b_L + 3\ \text{mm}$
t_L	Thickness of the near-surface mounted CFRP strips
b_L	Width of the near-surface mounted CFRP strips

1	Component D - Bonding Agent FRS-BA:	Consumption ρ_D: 500 g/m² - 800 g/m²
2	Component C - Epoxy Repair Mortar FRS-PC 11:	Layer thickness d_M: 4 mm - 30 mm
3	Component B - Epoxy Mortar FRS-CS:	Consumption ρ_B: 0,06 kg/m – 0,20 kg/m
4	Component A - CFRP strip FRS-L-S NSM:	thickness of CFRP strips t_L: 1,2 mm / 1,4 mm / 1,7 mm

Figures are not to scale

fischer C-Fiber Force Strengthening System	**Annex A5**
Product description Installed condition – near surface mounted CFRP strips	

Overview of the fischer C-Fiber Force Strengthening System – Specifications

Intended use
The fischer C-Fiber Force Strengthening System is used for strengthening the tensile reinforcement area of concrete elements like beams, slabs, walls and columns. It is intended to contribute to the increase of the structural capacity for static, quasi-static and dynamic high cycle fatigue loading of concrete elements according to the design rules.

Structural design
The structural design of strengthening layouts with the fischer C-Fiber Force strengthening system by near surface mounted CFRP strips and by externally bonded CFRP strips is the responsibility of an experienced structural engineer according to the national or international guidelines and regulations, in conjunction with this technical assessment as well as technical drawings and the MPII.
The fischer REINFORCE-FIX design software might provide design proposals for certain strengthening layouts for reinforced concrete elements.

Base materials
The intended use of the strengthening system as covered by this ETA covers concrete elements from normal weight reinforced concrete, whose properties enable assignment to concrete strength classes C12/15 to C50/60 according to EN 206-1:2013+A2:2021, with a mean surface tensile strength of at least ≥ 1,0 MPa with a sufficiently even and level surface. In case of the use of higher surface tensile strengths in the structural design, these values need to be verified on the concrete element to be strengthened by means of measurement of bond strength by pull-of tests acc. to EN 1542:1999.
The decision on the suitability and adequate pretreatment of the concrete surface remains the responsibility of an experienced structural engineer.

Installation and use conditions
The installations shall be performed by appropriately qualified personnel under the supervision of the responsible structural engineer. Installation works shall be performed in accordance with the layout given in the structural design without allocation or exchange of defined materials and geometries. All materials covered in the C-Fiber Force Strengthening System shall be used without manipulations. The types and geometries of CFRP strips covered by this assessment are listed in Annex C9. The width of the CFRP strips shall not be changed on the construction site. The CFRP strips may be cut to the required length in accordance with the manufacturer's product installation instructions (MPII).

Storage, transport, handling, preparation and mixing as well as installation works need to be performed according to the manufacturer's technical datasheets and manufacturer´s product installation instructions (MPII) and in alignment with national and international regulations.

The temperature range of use of the fischer C-Fiber Force Strengthening System is – 25 °C - + 40 °C after complete cure of the components. Reductions in load-bearing capacity due to the effects of temperature and other environmental conditions shall be taken into account in the structural design.

The fischer C-Fiber Force Strengthening System may be applied within an ambient temperature range of + 10 °C - + 40 °C if both surface temperature and ambient temperature are in range above dew point in accordance with the manufacturer´s product installation instructions (MPII) respectively manuals.

The curing times of the system components are listed below:

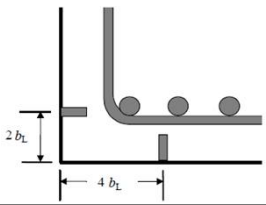
Temperature:	≥ 10 °C	≥ 20 °C	40 °C
FRS-BA	≥ 96 h	≥ 48 h	≥ 24 h
FRS-PC 11	≥ 96 h	≥ 48 h	≥ 24 h
FRS-CS	≥ 48 h	≥ 24 h	≥ 16 h

The kit should therefore cure for at least 48 h at standard conditions (21 °C) or at least 96 h at minimum installation temperature (10 °C) depending on the individual weather conditions.

Quality assurance of the application should be defined by the responsible structural engineer to ensure correct design, surface preparation, installation and cure of the kit in alignment with the manufacturers MPII and national regulations if applicable.

fischer C-Fiber Force Strengthening System	**Annex B1**
Intended use Specifications and installation conditions	

Deutsches Institut für Bautechnik DIBt

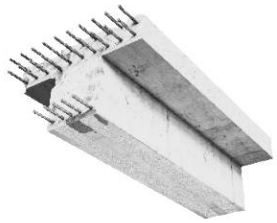
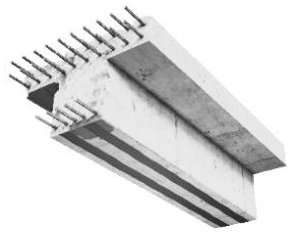
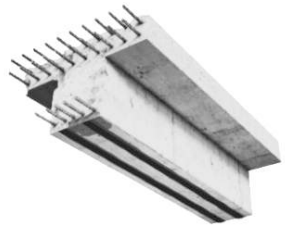
Table B2.1 Specifications and installation conditions of the strengthening system					
Concrete repair with FRS-PC 11 (Comp. C) and Bonding Agent FRS-BA (Comp. D)					
Concrete surface treatment	Removal of loose concrete particles and cleaning with a steel brush and vacuum or compressed air.				
System	Repair mortar FRS-PC 11 appl. wet in wet with bonding agent FRS-BA				
Recommended consumption of bonding agent FRS-BA d_B [kg/m²]	0,5 – 0,8				
Range of layer thickness of repair mortar FRS-PC 11 d_M [mm]	4 – 30				
Layer thickness of repair mortar FRS-PC 11 d_M [mm]	5	10	15	20	30
Corresponding consumption of repair mortar FRS-PC 11 [kg/m²]	10	20	30	40	60
Strengthening with externally bonded CFRP strips FRS-L-S / FRS-L-H (Comp. A) & FRS-CS (Comp. B)					
Concrete Surface treatment	Sand blasting	Shot peening	Grinding	Needle gun	
	Cleaning with vacuum or compressed air				
Recommended layer thickness d_G [mm]	1 – 5				
Approx. consumption of structural bonding agent FRS-CS [kg/m]	1 mm thickness	2 mm thickness	3 mm thickness	4 mm thickness	5 mm thickness
FRS-L-S / FRS-L-H b_l = 50 mm	0,10	0,20	0,30	0,40	0,50
FRS-L-S / FRS-L-H b_l = 75 mm	0,15	0,30	0,45	0,60	0,75
FRS-L-S / FRS-L-H b_l = 100 mm	0,20	0,40	0,60	0,80	1,00
Minimum edge distance a_r	At least equal to the concrete cover of the internal reinforcements				
Consumptions depend on the surface roughness of the concrete surface.					
Strengthening with near surface mounted CFRP strips FRS-L-S NSM (Comp. A) & FRS-CS (Comp. B)					
Surface treatment	Milling slots				
	Cleaning of slots with compressed air				
Width and thickness of the CFRP strip [mm]	10 × 1,7	15 × 1,4	20 × 1,2		
Recommended min. slot depth t_s [mm]	13	18	23		
Recommended slot width b_s [mm]	2,7 – 4,7	2,4 – 4,4	2,2 – 4,2		
Minimum slot width using the FRS-GA $b_{s,min}$ [mm]	4,0				
Approx. consumption of structural bonding agent FRS-CS [kg/m]	0,060 – 0,075	0,075 – 0,090	0,090 – 0,200		
Minimum edge distance a_r	$a_r \geq \min\begin{pmatrix} 2 \cdot b_f \\ 30\ \text{mm} \\ d_g \end{pmatrix}$ where b_f: width of CFRP strip; d_g: maximum aggregate size 				
Minimum slot-slot distance a_l	At least, $a_l \geq b_l$, without load reduction $a_l \geq 2 \cdot b_l$				
Minimum concrete cover c	At least $c \geq t_s$ + 5 mm, depending on the working and display accuracy of the devices used				
Consumptions depend on the width and depth of the cut.					

fischer C-Fiber Force Strengthening System	**Annex B2**
Intended use Specifications and installation conditions	

Graphic depictions of the strengthening method – Externally bonded CFRP strips (part I)

Depiction of the stages of concrete repair and strengthening of concrete structures with the fischer C-Fiber Force Strengthening System with externally bonded CFRP strips

The hereby presented installation steps do not substitute the complete installation instruction manuals and might not be complete. For detailed application and processing information consult the corresponding Manufacturer´s Product Installation Instructions (MPII).

	Application of Bonding Agent FRS-BA as a thin layer on cleaned, fractured, or damaged areas of the concrete as well as on the rust-free, embedded steel reinforcing bars for corrosion protection if exposed. *(The necessity of concrete repair is dependent on the actual condition of the individual concrete element to be strengthened)*
	Application of the Epoxy Repair Mortar FRS-PC 11 on the damaged concrete, directly installed into the wet, non-cured Bonding Agent FRS-BA. *(The necessity of concrete repair is dependent on the actual condition of the individual concrete element to be strengthened)*
	Preparation and roughening of the concrete surface to be strengthened for the subsequent bonding of CFRP strips by either sand blasting, shot peening, grinding or similar in the areas, where the CFRP strips are to be applied. After the roughening, the coarse concrete aggregates ≥ 4 mm shall be visible.
	Application of the Epoxy Mortar FRS-CS as a scratch coat on the prepared concrete surface as well as on the surface of the FRS-L-S and FRS-L-H CFRP strips in a roof shaped manner by considering the recommended consumptions rates to achieve a mortar layer thickness between 1 mm to 5 mm after application.
	Application of the fischer FRS-L-S or FRS-L-H externally bonded CFRP strips to the surface of the concrete element to be strengthened. After the CFRP strips are placed on the concrete surface, the excess FRS-CS Epoxy Mortar shall be visible on the sides of the CFRP strips.

fischer C-Fiber Force Strengthening System	**Annex B3**
Intended use Overview of the stages of the repair and strengthening of concrete structures with externally bonded CFRP strips	

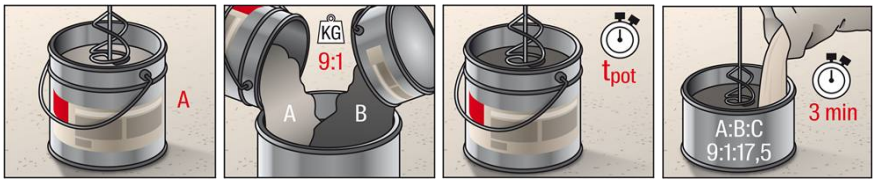
Graphic depictions of the strengthening method - Externally bonded CFRP strips (part II)

Depiction of the stages of concrete repair and strengthening of concrete structures with the fischer C-Fiber Force Strengthening System with externally bonded CFRP strips

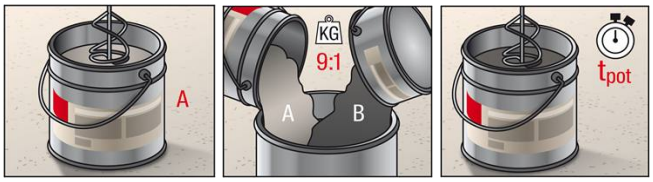
The hereby presented installation steps do not substitute the complete installation instruction manuals and might not be complete. For detailed application and processing information consult the corresponding Manufacturer´s Product Installation Instructions (MPII).

Concrete Repair using the Epoxy Repair Mortar FRS-PC 11 with the Bonding Agent FRS-BA:

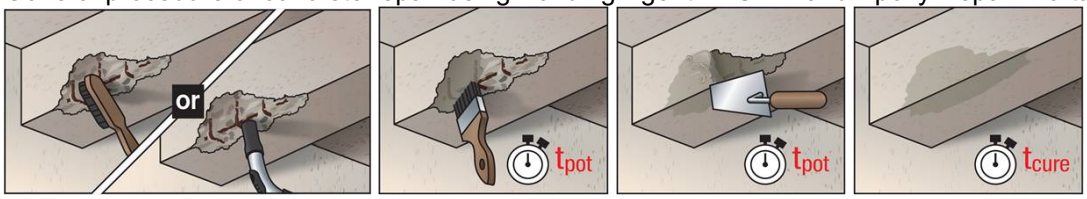
Preparation of the Epoxy Repair Mortar FRS-PC 11 (Comp. C):



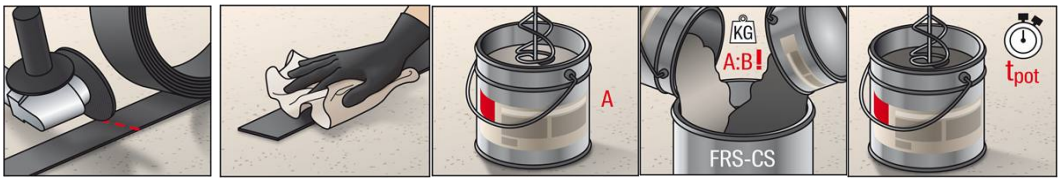
Preparation of the Bonding Agent FRS-BA (Comp. D):

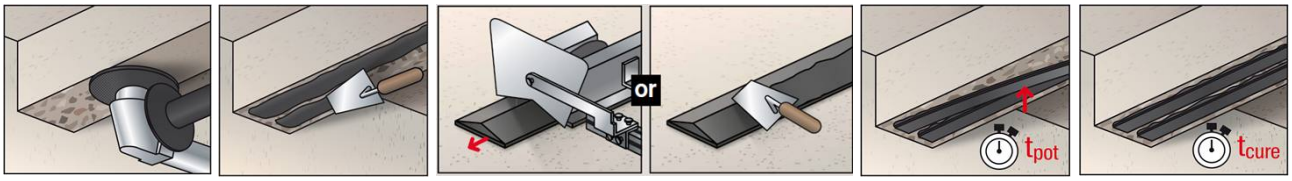


General procedure of concrete repair using Bonding Agent FRS-BA and Epoxy Repair Mortar FRS-PC 11:



Installation of FRS-L-S and FRS-L-H CFRP strips (Comp. A) using the Epoxy Mortar FRS-CS (Comp. B):





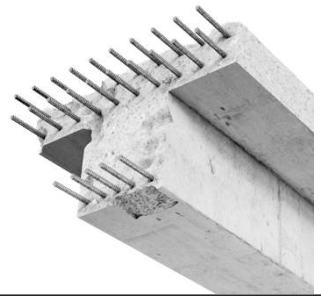
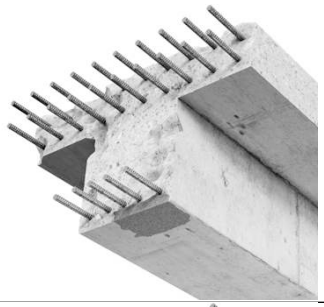
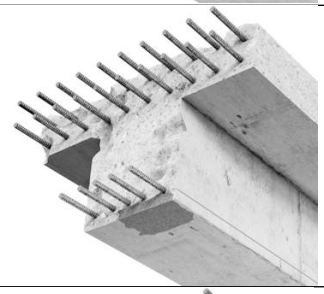
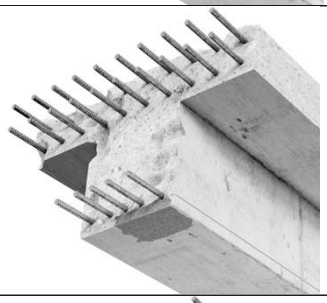
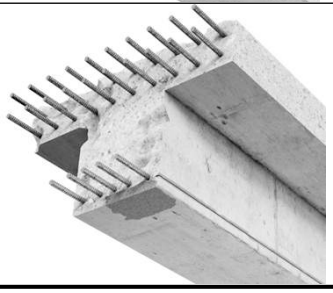
For further information (e.g. on pot life, hardening time, mixing time) on the FRS-BA, FRS-PC 11, FRS-CS consult the corresponding technical data sheets, product labels, MPII.

fischer C-Fiber Force Strengthening System	
Intended use Overview of the stages of the repair and strengthening of concrete structures with externally bonded CFRP Strips	**Annex B4**

Graphic depictions of the strengthening method – Near surface mounted CFRP strips (Part I)

Depiction of the stages of concrete repair and strengthening of concrete structures with the fischer C-Fiber Force Strengthening System with near surface mounted CFRP strips

The hereby presented installation steps do not substitute the complete installation instruction manuals and might not be complete. For detailed application and processing information consult the corresponding Manufacturer´s Product Installation Instructions (MPII).

	Application of Bonding Agent FRS-BA as a thin layer on cleaned, fractured, or damaged areas of the concrete as well as on the rust-free, embedded steel reinforcing bars for corrosion protection if exposed. *(The necessity of concrete repair is dependent on the actual condition of the individual concrete element to be strengthened)*
	Application of the Epoxy Repair Mortar FRS-PC 11 on the damaged concrete, directly installed into the wet, non-cured Bonding Agent FRS-BA. *(The necessity of concrete repair is dependent on the actual condition of the individual concrete element to be strengthened)*
	Preparation of the concrete surface to be strengthened for bonding by cutting slots with adequate depth and width into the concrete and subsequent thorough cleaning of the slot with compressed air or vacuum.
	Application respectively injection of the structural bonding agent for CFRP strips Epoxy Mortar FRS-CS into the concrete slots ensuring a complete filling of the slots.
	Leveled and centered application of the FRS-L-S NSM near surface mounted CFRP strips into the slots of the concrete element to be strengthened filled with the Epoxy Mortar FRS-CS. After the CFRP strips are placed in the slots, excess FRS-CS Epoxy Mortar shall be visible on both sides of the CFRP strips. The excess is removed to create a level surface appearance.

fischer C-Fiber Force Strengthening System	**Annex B5**
Intended use Overview of the stages of the repair and strengthening of concrete structures with near surface mounted CFRP strips	

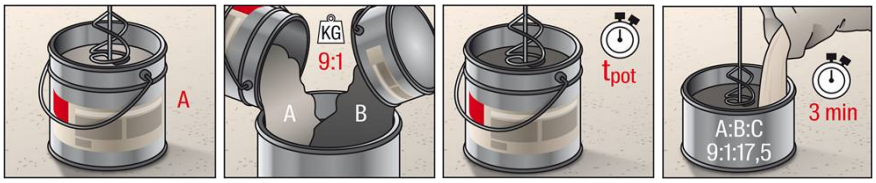
Graphic depictions of the strengthening method – Near surface mounted CFRP strips (Part II)

Depiction of the stages of concrete repair and strengthening of concrete structures with the fischer C-Fiber Force Strengthening System with near surface mounted CFRP strips

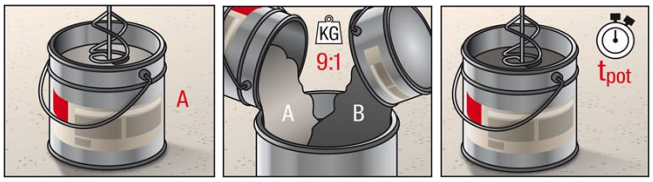
The hereby presented installation steps do not compensate for an installation instruction and are not exhaustive. For detailed application and processing information consult the corresponding Manufacturer Product Installation Instructions (MPII).

Concrete Repair using the Epoxy Repair Mortar FRS-PC 11 with the Bonding Agent FRS-BA

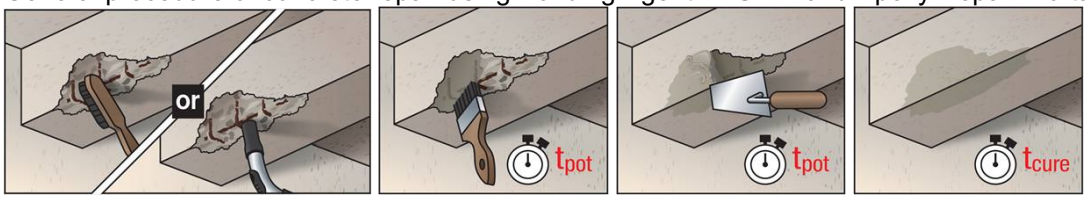
Preparation of the Epoxy Repair Mortar FRS-PC 11 (Comp. C):



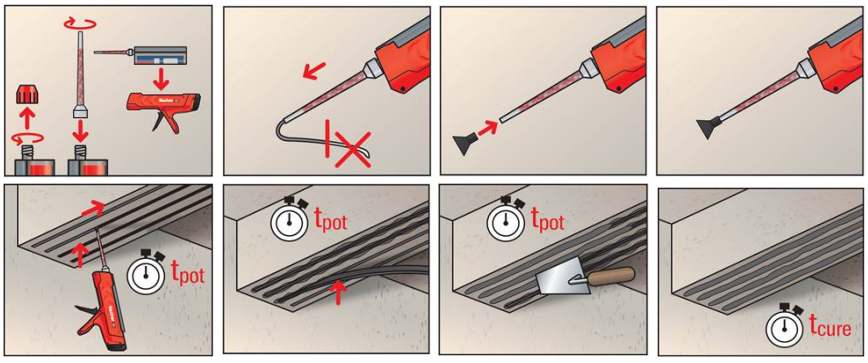
Preparation if the Bonding Agent FRS-BA (Comp. D):



General procedure of concrete repair using Bonding Agent FRS-BA and Epoxy Repair Mortar FRS-PC 11:



Installation of FRS-L-S NSM CFRP strips (Comp. A) using the Epoxy Mortar FRS-CS / FRS-CS 585 S cartridge system (Comp. B):



fischer C-Fiber Force Strengthening System	
Intended use Overview of the stages of the repair and strengthening of concrete structures with near surface mounted CFRP strips	**Annex B6**

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Table C1.1 Characteristics of the structural bonding agent FRS-CS	
Appearance - Component A - Component B - Mixture of A and B (4:1)	 Highly viscous paste of beige colour with visible aggregates Highly viscous paste of black colour with visible aggregates Smooth, highly viscous paste of grey colour with visible aggregates
Density - Component A - Component B - Mixture of A and B (4:1)	 1,92 g/cm³ ± 0,05 g/cm³ 1,63 g/cm³ ± 0,05 g/cm³ 1,86 g/cm³ ± 0,05 g/cm³
Mixing ratio by weight	4 : 1
Elastic modulus in compression** and tension:***	≥ 7500 MPa
Tensile strength:***	≥ 35 MPa
Minimum workability time - at minimum installation temperature (10°C) and maximum container size (10 kg)* - at standard conditions (21 °C) and maximum container size (10 kg)* - at maximum installation temperature (40 °C) and maximum container size (10 kg)*	 120 min. 80 min. 25 min.
Minimum curing time - at minimum installation temperature (10 °C) - at standard conditions (21 °C) - at maximum installation temperature (40 °C)	 4 days 2 days 1 day

*According to EN ISO 9514:2019.
**According to EN 13412:2006.
***According to EN ISO 527-1:2019, after 7 days at standard conditions.

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Table C2.1 Glass transition temperature of the structural bonding agent FRS-CS

Curing conditions and curing times		Glass transition temperature [°C]
- after 7 days curing at 21 °C ± 2 °C, 50% Rh.	T_{Ggi}	54 – 59 *; 55 – 59 *

Determination of the glass transition temperature was performed using the first heating cycle.

*Due to the post-curing of the epoxy resin, which is superimposed on the measurement of the glass transition temperature, only one temperature range can be specified for the glass transition temperatures.

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Table C3.1 Characteristics of the repair mortar FRS-PC 11	
Appearance - Component A - Component B - Component C - Mixture of A, B and C (3,6 : 0,4 : 7)	 Highly viscous paste of white colour Low viscosity, fluent liquid of black colour Free flowing coarse aggregates of beige colour Firm thixotropic mortar of light grey colour
Density - Component A - Component B - Component C - Mixture of A and B (3,6 : 0,4 : 7)	 2,12 g/cm³ ± 0,05 g/cm³ 0,99 g/cm³ ± 0,05 g/cm³ 2,20 g/cm³ ± 0,05 g/cm³ 2,12 g/cm³ ± 0,05 g/cm³
Mixing ratio by weight	3,6 : 0,4 : 7
Elastic modulus in compression**	≥ 20.000 MPa
Minimum workability time - at minimum installation temperature (10 °C) and maximum container size (11 kg)* - at standard conditions (21 °C) and maximum container size (11 kg)* - at maximum installation temperature (40 °C) and maximum container size (11 kg)*	 180 min. 80 min. 25 min.
Minimum curing time - at minimum installation temperature (10 °C) - at standard conditions (21 °C) - at maximum installation temperature (40 °C)	 4 days 2 days 1 day

*According to EN ISO 9514:2019.
**According to EN 13412:2006.

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Table C4.1 Glass transition temperature of the repair mortar FRS-PC 11

Curing conditions and curing time		Glass transition temperature [°C]
- after 7 days curing at 21 °C ± 2 °C, 50% Rh.	T_{Ggi}	59 – 63 * 59 – 63 *

Determination of the glass transition temperature was performed using the first heating cycle.

*Due to the post-curing of the epoxy resin, which is superimposed on the measurement of the glass transition temperature, only one temperature range can be specified for the glass transition temperatures.

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Table C5.1 Flexural strength of the structural bonding agent FRS-CS		
Curing conditions and curing times		**Flexural strength [MPa]**
- after 1 day curing at 10 °C ± 2 °C, 50% Rh. **Mean value** **Characteristic value**	f_{Gflij} $\boldsymbol{f_{Gflmj}}$ $\boldsymbol{f_{Gflkj}}$	26,0; 25,7; 25,6; **25,8** **25,1**
- after 7 days curing at 10 °C ± 2 °C, 50% Rh. **Mean value** **Characteristic value**	f_{Gflij} $\boldsymbol{f_{Gflmj}}$ $\boldsymbol{f_{Gflkj}}$	34,2; 34,0; 32,4; **33,5** **30,2**
- after 14 days curing at 10 °C ± 2 °C, 50% Rh. **Mean value** **Characteristic value**	f_{Gflij} $\boldsymbol{f_{Gflmj}}$ $\boldsymbol{f_{Gflkj}}$	34,6; 31,7; 33,2; **33,2** **28,3**
- after 7 days curing at 21 °C ± 2 °C, 50% Rh. **Mean value** **Characteristic value**	f_{Gfli} $\boldsymbol{f_{Gtflm}}$ $\boldsymbol{f_{Gflk}}$	34,0; 31,3; 29,5; **31,6** **24,0**

fischer C-Fiber Force Strengthening System

Annex C5

Performance
Flexural strength of the structural bonding agent FRS-CS cured at standard environmental or minimum temperature of installation

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Table C6.1 Compressive strength of the structural bonding agent FRS-CS		
Curing conditions and curing time		**Compressive strength [MPa]**
- after 1 day curing at 10 °C ± 2 °C, 50% Rh. **Mean value** **Characteristic value**	f_{Gcij} $\boldsymbol{f_{Gcmj}}$ $\boldsymbol{f_{Gckj}}$	51,2; 50,1; 51,4; 48,7; 52,9; 47,5; **50,3** **46,0**
- after 7 days curing at 10 °C ± 2 °C, 50% Rh. **Mean value** **Characteristic value**	f_{Gcij} $\boldsymbol{f_{Gcmj}}$ $\boldsymbol{f_{Gckj}}$	87,8; 85,9; 87,5; 84,3; 86,6; 82,6; **85,8** **81,4**
- after 14 days curing at 10 °C ± 2 °C, 50% Rh. **Mean value** **Characteristic value**	f_{Gcij} $\boldsymbol{f_{Gcmj}}$ $\boldsymbol{f_{Gckj}}$	91,6; 91,3; 91,7; 90,1; 90,2; 89,1; **90,7** **88,4**
- after 7 days curing at 21 °C ± 2 °C, 50% Rh. **Mean value** **Characteristic value**	f_{Gci} $\boldsymbol{f_{Gcm}}$ $\boldsymbol{f_{Gck}}$	89,9; 87,6; 89,8; 89,4; 88,8; 90,7; **89,4** **87,0**

fischer C-Fiber Force Strengthening System	**Annex C6**
Performance Compressive strength of the structural bonding agent FRS-CS cured at standard environmental or at minimum temperature of installation	

Deutsches Institut für Bautechnik DIBt

Table C7.1 Flexural strength of the repair mortar FRS-PC 11		
Curing conditions and curing time		**Flexural strength [MPa]**
- after 1 day curing at 10 °C ± 2 °C, 50% Rh. **Mean value** **Characteristic value**	f_{Mflij} $\boldsymbol{f_{Mflmj}}$ $\boldsymbol{f_{Mflkj}}$	26,3; 25,7; 25,6; **25,9** **24,6**
- after 7 days curing at 10 °C ± 2 °C, 50% Rh. **Mean value** **Characteristic value**	f_{Mflij} $\boldsymbol{f_{Mflmj}}$ $\boldsymbol{f_{Mflkj}}$	37,5; 36,9; 38,7; **37,7** **34,6**
- after 14 days curing at 10 °C ± 2 °C, 50% Rh. **Mean value** **Characteristic value**	f_{Mflij} $\boldsymbol{f_{Mflmj}}$ $\boldsymbol{f_{Mflkj}}$	40,5; 43,0; 42,4; **42,0** **37,6**
- after 7 days curing at 21 °C ± 2 °C, 50% Rh. **Mean value** **Characteristic value**	f_{Mfli} $\boldsymbol{f_{Mtflm}}$ $\boldsymbol{f_{Mflk}}$	42,4; 42,3; 41,6; **42,1** **41,4**

fischer C-Fiber Force Strengthening System	**Annex C7**
Performance Flexural strength of the repair mortar FRS-PC 11 cured at standard environmental or at minimum temperature of installation	

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Table C8.1 Compressive strength of the repair mortar FRS-PC 11		
Curing conditions and curing time		**Compressive strength [MPa]**
- after 1 day curing at 10 °C ± 2 °C, 50% Rh. **Mean value** **Characteristic value**	f_{Mcij} $\boldsymbol{f_{Mcmj}}$ $\boldsymbol{f_{Mckj}}$	91,4; 88,1; 87,8; 87,1; 86,9; 87,3; **88,1** **84,4**
- after 7 days curing at 10 °C ± 2 °C, 50% Rh. **Mean value** **Characteristic value**	f_{Mci} $\boldsymbol{f_{Mcm}}$ $\boldsymbol{f_{Mck}}$	137,6; 137,1; 133,5; 135,6; 139,2; 134,3; **136,2** **131,5**
- after 14 days curing at 10 °C ± 2 °C, 50% Rh. **Mean value** **Characteristic value**	f_{Mci} $\boldsymbol{f_{Mcm}}$ $\boldsymbol{f_{Mck}}$	146,1; 146,6; 144,3; 143,4; 144,6; 143,8; **144,8** **142,0**
- after 7 days curing at 21 °C ± 2 °C, 50% Rh. **Mean value** **Characteristic value**	f_{Mci} $\boldsymbol{f_{Mcm}}$ $\boldsymbol{f_{Mck}}$	147,0; 150,2; 147,4; 148,4; 146,3; 152,6; **148,7** **143,5**

fischer C-Fiber Force Strengthening System	**Annex C8**
Performance Compressive strength of the repair mortar FRS-PC 11 cured at standard environmental or at minimum temperature of installation	

Table C9.1 Characteristics of the FRS-L-H CFRP strips			
Type of application	Externally bonded (EB) Reinforcement		
Minimum coil diameter	≥ 800 mm		
Fiber volume content	≥ 67 % by volume*		
Glass transition temperature	≥ 100 °C**		
Geometry	Width b_l [mm]	Thickness t_l [mm]	Cross section area [mm²]
FRS-L-H 50 × 1,2 mm	50	1,2	60
FRS-L-H 50 × 1,4 mm	50	1,4	70
FRS-L-H 75 × 1,2 mm	75	1,2	90
FRS-L-H 75 × 1,4 mm	75	1,4	105
FRS-L-H 100 × 1,2 mm	100	1,2	120
FRS-L-H 100 × 1,4 mm	100	1,4	140

Table C9.2 Characteristics of the FRS-L-S CFRP strips			
Type of application	Externally bonded (EB) Reinforcement		
Minimum coil diameter	≥ 800 mm		
Fiber volume content	≥ 67 % by volume*		
Glass transition temperature	≥ 100 °C**		
Geometry	Width b_l [mm]	Thickness t_l [mm]	Cross section area [mm²]
FRS-L-S 50 × 1,2 mm	50	1,2	60
FRS-L-S 50 × 1,4 mm	50	1,4	70
FRS-L-S 75 × 1,2 mm	75	1,2	90
FRS-L-S 75 × 1,4 mm	75	1,4	105
FRS-L-S 100 × 1,2 mm	100	1,2	120
FRS-L-S 100 × 1,4 mm	100	1,4	140

Table C9.3 Characteristics of the FRS-L-S NSM CFRP strips			
Type of application	Near surface mounted (NSM) Reinforcement		
Minimum coil diameter	≥ 800 mm		
Fiber volume content	≥ 67 % by volume*		
Glass transition temperature	≥ 100 °C**		
Geometry	Width b_l [mm]	Thickness t_l [mm]	Cross section area [mm²]
FRS-L-S NSM 10 × 1,7 mm	10	1,7	17
FRS-L-S NSM 15 × 1,4 mm	15	1,4	21
FRS-L-S NSM 20 × 1,2 mm	20	1,2	24

Types of CFRP strips FRS-L-H and FRS-L-S / FRS-L-S NSM only differ in the type of fibers used but are identical in their matrix material and fiber volume content as well as production process.

*According to EN 2564:2018.
**According to EN 12614:2005.

fischer C-Fiber Force Strengthening System	**Annex C9**
Performance Types and Geometries of CFRP strips	

Deutsches Institut für Bautechnik DIBt

Table C10.1 Modulus of elasticity, tensile strength and ultimate strain of CFRP strips FRS-L-H		
Essential characteristic		**Performance**
Modulus of elasticity [GPa]	E_{Li}	206; 206; 191; 199; 205; 194; 202; 195; 191; 191; 206; 201; 200; 199; 199; 209; 206; 208; 203; 205
Mean value [GPa]	$\boldsymbol{E_{Lm}}$	**201**
Tensile strength [MPa]	f_{Li}	3499; 3513; 3084; 3226; 3385; 3524; 3230; 3289; 3317; 3196; 3607; 3031; 3679; 3302; 3554; 3609; 3601; 3774; 3369; 3429
Mean value [MPa]	$\boldsymbol{f_{Lm}}$	**3411**
Characteristic value of the tensile strength [MPa]	$\boldsymbol{f_{Lk}}$	**3056**
Ultimate strain [%]	ε_{Lui}	1,80; 1,65; 1,67; 1,63; 1,64; 1,76; 1,60; 1,64; 1,86; 1,63; 1,71; 1,42; 1,76; 1,59; 1,71; 1,68; 1,70; 1,73; 1,59; 1,77
Mean value [%]	$\boldsymbol{\varepsilon_{Lum}}$	**1,68**

Please note that the values of tensile properties in **Annex C10** were determined from five separate tensile measurements each of all characteristic cross sections of the type FRS-L-H.

Table C11.1 Modulus of elasticity, tensile strength and ultimate strain of CFRP strips FRS-L-S and FRS-L-S NSM

Essential characteristic		Performance
Modulus of elasticity [GPa]	E_{Li}	173; 169; 178; 170; 177; 177; 175; 167; 170; 178; 176; 178; 181; 177; 177; 175; 173; 178; 174; 170; 167; 169; 170; 170; 173; 176; 167; 163; 175; 166; 173; 173; 176; 173; 172; 171; 170; 174; 171; 169; 181; 178; 176; 177; 175; 177; 178; 174; 170; 174; 176; 178; 173; 181; 173; 173; 172; 170; 172; 174; 171; 170; 167; 176; 169; 171; 172; 170; 172; 171
Mean value [GPa]	E_{Lm}	**173**
Tensile strength [MPa]	f_{Li}	2959; 3057; 2929; 3047; 2989; 3213; 3203; 3193; 3318; 3282; 3060; 3160; 3183; 2911; 3164; 3287; 3094; 2954; 3132; 2966; 2866; 2878; 2913; 2803; 3086; 3040; 2994; 2894; 3136; 2871; 3135; 3278; 3239; 3230; 3155; 3137; 3218; 3171; 3192; 3247; 2241; 2848; 3297; 3111; 2533; 3104; 3238; 3115; 3268; 3230; 2825; 2874; 2839; 2887; 2987; 2935; 3155; 2969; 2994; 3039; 2809; 2807; 2824; 2847; 2779; 3316; 3245; 3220; 3419; 3438;
Mean value [MPa]	f_{Lm}	**3054**
Characteristic value of the tensile strength [MPa]	f_{Lk}	**2701**
Ultimate strain [%]	ε_{Lui}	1,69; 1,80; 1,66; 1,76; 1,67; 1,76; 1,70; 1,86; 1,89; 1,84; 1,72; 1,77; 1,89; 1,68; 1,73; 1,82; 1,88; 1,69; 1,75; 1,73; 1,64; 1,77; 1,94; 1,67; 1,78; 1,63; 1,70; 1,73; 1,69; 1,70; 1,75; 1,96; 1,90; 1,78; 1,72; 1,76; 1,82; 1,81; 1,69; 1,86; 1,52; 1,53; 1,81; 1,68; 1,69; 1,67; 1,75; 1,76; 1,79; 1,77; 1,65; 1,57; 1,61; 1,63; 1,85; 1,67; 1,78; 1,69; 1,68; 1,78; 1,77; 1,65; 1,68; 1,55; 1,68; 1,82; 1,88; 1,69; 1,75; 1,73; 1,77; 1,65; 1,68; 1,55; 1,68; 1,87; 1,79; 1,84; 1,92; 1,99;
Mean value [%]	ε_{Lum}	**1,74**

Please note that the values of tensile properties in **Annex C11** were determined from at least five separate tensile measurements each of all characteristic cross sections of the type FRS-L-S and FRS-L-S NSM.

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Table C12.1 Resistance of CFRP strips FRS-L-H to storage in alkaline environment (pH > 11,0) at maximum temperature for the intended use

Essential characteristic		Performance
Modulus of elasticity [GPa]	E_{Lai}	192; 196; 198; 196; 200
Mean value [GPa]	$\boldsymbol{E_{\mathrm{Lam}}}$	**196**
Ratio of modulus of elasticity after / before exposure ($\boldsymbol{R_{\mathrm{LEa}}}$=$\boldsymbol{E_{\mathrm{Lam}}}$ / $\boldsymbol{E_{\mathrm{Lm}}}$)	$\boldsymbol{R_{\mathrm{LEa}}}$	**0,98**
Tensile strength [MPa]	f_{Lai}	3135; 3016; 3021; 3243; 3200
Mean value [MPa]	$\boldsymbol{f_{\mathrm{Lam}}}$	**3123**
Ratio of tensile strength after / before exposure ($\boldsymbol{R_{\mathrm{Lfa}}}$=$\boldsymbol{f_{\mathrm{Lam}}}$ / $\boldsymbol{f_{\mathrm{Lm}}}$)	$\boldsymbol{R_{Lfa}}$	**0,92**
Ultimate strain [%]	$\varepsilon_{\mathrm{Luai}}$	1,90; 1,48; 1,69; 1,72; 1,72
Mean value [%]	$\boldsymbol{\varepsilon_{\mathrm{Luam}}}$	**1,70**
Ratio of ultimate strain after / before exposure ($\boldsymbol{R_{\mathrm{L\varepsilon ua}}} = \boldsymbol{\varepsilon_{\mathrm{Luam}}}/\boldsymbol{\varepsilon_{\mathrm{Lum}}}$)	$\boldsymbol{R_{\mathrm{L\varepsilon ua}}}$	**1,01**

Please note that the values of tensile properties in **Annex C12** were determined from five measurements of FRS-L-H CFRP strips with 1,2 mm thickness after 1800 h exposure to alkaline solution (pH > 11,0) at maximum temperature of use (40 °C).

fischer C-Fiber Force Strengthening System	**Annex C12**
Performance Resistance of FRS-L-H CFRP strips to storage in alkaline environment (pH > 11,0) at maximum temperature according to the intended use (40 °C)	

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Table C13.1 Resistance of CFRP strips FRS-L-H to storage in alkaline environment (pH > 13,7) at maximum temperature for the intended use

Essential characteristic		**Performance**
Modulus of elasticity [GPa] **Mean value [GPa]**	E_{Lai} $\boldsymbol{E_{\mathrm{Lam}}}$	194; 196; 184; 192; 194; **192**
Ratio of modulus of elasticity after / before exposure **(R_{LEa}=E_{Lam} / E_{Lm})**	$\boldsymbol{R_{\mathrm{LEa}}}$	**0,96**
Tensile strength [MPa] **Mean value [MPa]**	f_{Lai} $\boldsymbol{f_{\mathrm{Lam}}}$	3054; 3407; 3153; 2932; 3356; **3180**
Ratio of tensile strength after / before exposure **(R_{Lfa}=f_{Lam} / f_{Lm})**	$\boldsymbol{R_{Lfa}}$	**0,93**
Ultimate strain [%] **Mean value [%]**	$\varepsilon_{\mathrm{Luai}}$ $\boldsymbol{\varepsilon_{\mathrm{Luam}}}$	1,66; 1,68; 1,65; 1,53; 1,68; **1,64**
Ratio of ultimate strain after / before exposure **($R_{\mathrm{L\varepsilon ua}} = \varepsilon_{\mathrm{Luam}}/\varepsilon_{\mathrm{Lum}}$)**	$\boldsymbol{R_{\mathrm{L\varepsilon ua}}}$	**0,98**

Please note that the following values of tensile properties in **Annex C13** were determined from measurements of strips with 1,2 mm thickness after 1800 h exposure to alkaline solution (pH > 13,7) at maximum temperature of use (40 °C).

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Table C14.1 Resistance of CFRP strips FRS-L-S & FRS-L-S NSM to storage in alkaline environment (pH > 11,0) at maximum temperature for the intended use

Essential characteristic		**Performance**
Modulus of elasticity [GPa] **Mean value [GPa]**	E_{Lai} $\boldsymbol{E_{Lam}}$	171; 168; 173; 172; 170; **171**
Ratio of modulus of elasticity after / before exposure **(R_{LEa}=E_{Lam} / E_{Lm})**	$\boldsymbol{R_{LEa}}$	**0,99**
Tensile strength [MPa] **Mean value [MPa]**	f_{Lai} $\boldsymbol{f_{Lam}}$	3167; 3175; 3122; 3086; 3039; **3118**
Ratio of tensile strength after / before exposure **(R_{Lfa}=f_{Lam} / f_{Lm})**	$\boldsymbol{R_{Lfa}}$	**1,02**
Ultimate strain [%] **Mean value [%]**	ε_{Luai} $\boldsymbol{\varepsilon_{Luam}}$	1,81; 1,83; 1,79; 1,73; 1,77; **1,79**
Ratio of ultimate strain after / before exposure **($R_{L\varepsilon ua} = \varepsilon_{Luam}/\varepsilon_{Lum}$)**	$\boldsymbol{R_{L\varepsilon ua}}$	**1,02**

Please note that the following values of tensile properties in **Annex C14** were determined from measurements of strips with 1,2 mm thickness after 1800 h exposure to alkaline solution (pH > 11,0) at maximum temperature of use (40 °C).

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Table C15.1 Resistance of CFRP strips FRS-L-S & FRS-L-S NSM to storage in alkaline environment (pH > 13,7) at maximum temperature for the intended use

Essential characteristic		Performance
Modulus of elasticity [GPa] **Mean value [GPa]**	E_{Lai} $\boldsymbol{E_{\mathrm{Lam}}}$	170; 171; 166; 169; 172; **170**
Ratio of modulus of elasticity after / before exposure **(R_{LEa}=E_{Lam} / E_{Lm})**	$\boldsymbol{R_{\mathrm{LEa}}}$	**0,98**
Tensile strength [MPa] **Mean value [MPa]**	f_{Lai} $\boldsymbol{f_{\mathrm{Lam}}}$	2632; 2868; 2647; 2819; 2835; **2760**
Ratio of tensile strength after / before exposure **(R_{Lfa}=f_{Lam} / f_{Lm})**	$\boldsymbol{R_{\mathrm{Lfa}}}$	**0,90**
Ultimate strain [%] **Mean value [%]**	$\varepsilon_{\mathrm{Luai}}$ $\boldsymbol{\varepsilon_{\mathrm{Luam}}}$	1,64; 1,76; 1,67; 1,73; 1,64; **1,69**
Ratio of ultimate strain after / before exposure **($R_{\mathrm{L\varepsilon ua}} = \varepsilon_{\mathrm{Luam}}/\varepsilon_{\mathrm{Lum}}$)**	$\boldsymbol{R_{\mathrm{L\varepsilon ua}}}$	**0,97**

Please note that the following values of tensile properties in **Annex C15** were determined from measurements of strips with 1,2 mm thickness after 1800 h exposure to alkaline solution (pH > 13,7) at maximum temperature of use (40 °C).

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Table C16.1 Resistance of FRS-L-H CFRP strips in alkaline environment (pH > 11,0) under long-term load at maximum temperature for the intended use

Essential characteristic		Performance
Modulus of elasticity [GPa]	E_{Lai}	199; 192; 185; 190; 187
Mean value [GPa]	$\boldsymbol{E_{\mathrm{Lam}}}$	**191**
Ratio of modulus of elasticity after / before exposure ($\boldsymbol{R_{\mathrm{LEa}}=E_{\mathrm{Lam}}/E_{\mathrm{Lm}}}$)	$\boldsymbol{R_{\mathrm{LEa}}}$	**0,95**
Tensile strength [MPa]	f_{Lai}	3357; 3230; 3177; 3216; 3240
Mean value [MPa]	$\boldsymbol{f_{\mathrm{Lam}}}$	**3244**
Ratio of tensile strength after / before exposure ($\boldsymbol{R_{\mathrm{Lfa}}=f_{\mathrm{Lam}}/f_{\mathrm{Lm}}}$)	$\boldsymbol{R_{\mathrm{Lfa}}}$	**0,95**
Ultimate strain [%]	$\varepsilon_{\mathrm{Luai}}$	1,79; 1,68; 1,57; 1,75; 2,00
Mean value [%]	$\boldsymbol{\varepsilon_{\mathrm{Luam}}}$	**1,76**
Ratio of ultimate strain after / before exposure ($\boldsymbol{R_{\mathrm{L\varepsilon ua}}=\varepsilon_{\mathrm{Luam}}/\varepsilon_{\mathrm{Lum}}}$)	$\boldsymbol{R_{\mathrm{L\varepsilon ua}}}$	**1,05**

Please note that the following values of tensile properties in **Annex C16** were determined from measurements of strips with 1,2 mm thickness after 1800 h exposure to alkaline solution (pH > 11,0) at maximum temperature of use (40 °C) and a permanent load of 50 % f_{LM}.

fischer C-Fiber Force Strengthening System

Annex C16

Performance
Resistance of FRS-L-H CFRP strips to long term load in alkaline environment (pH > 11,0) at maximum temperature according to the intended use (40 °C)

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Table C17.1 Resistance of FRS-L-S and FRS-L-S NSM CFRP strips in alkaline environment (pH > 11,0) under long-term load at maximum temperature for the intended use

Essential characteristic		Performance
Modulus of elasticity [GPa]	E_{Lai}	—†; 157; 163; 160; 160
Mean value [GPa]	$\boldsymbol{E_{\mathrm{Lam}}}$	**160**
Ratio of modulus of elasticity after / before exposure ($\boldsymbol{R_{\mathrm{LEa}}=E_{\mathrm{Lam}}/E_{\mathrm{Lm}}}$)	$\boldsymbol{R_{\mathrm{LEa}}}$	**0,92**
Tensile strength [MPa]	f_{Lai}	—†; 2699; 2695; 2790; 2703
Mean value [MPa]	$\boldsymbol{f_{\mathrm{Lam}}}$	**2722**
Ratio of tensile strength after / before exposure ($\boldsymbol{R_{\mathrm{Lfa}}=f_{\mathrm{Lam}}/f_{\mathrm{Lm}}}$)	$\boldsymbol{R_{\mathrm{Lfa}}}$	**0,89**
Ultimate strain [%]	$\varepsilon_{\mathrm{Luai}}$	—†; 1,73; 1,69; 1,85; 1,40
Mean value [%]	$\boldsymbol{\varepsilon_{\mathrm{Luam}}}$	**1,67**
Ratio of ultimate strain after / before exposure ($\boldsymbol{R_{\mathrm{L\varepsilon ua}}=\varepsilon_{\mathrm{Luam}}/\varepsilon_{\mathrm{Lum}}}$)	$\boldsymbol{R_{\mathrm{L\varepsilon ua}}}$	**0,95**

Please note that the following values of tensile properties in **Annex C17** were determined from measurements of strips with 1,2 mm thickness after 1800 h exposure to alkaline solution (pH > 11,0) at maximum temperature of use (40 °C) and a permanent load of 50 % f_{LM}.

† Measurement invalid.

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Table C18.1 Characteristics of the Bonding Agent FRS-BA	
Appearance - Component A - Component B - Mixture of A and B (9 : 1)	 Highly viscous paste of white colour Low viscosity, fluent liquid of black colour Medium viscosity liquid of light grey colour
Density - Component A - Component B - Mixture of A and B (9 : 1)	 2,12 g/cm³ ± 0,05 g/cm³ 0,99 g/cm³ ± 0,05 g/cm³ 2,01 g/cm³ ± 0,05 g/cm³
Mixing ratio by weight	9 : 1
Elastic modulus in tension*	≥ 7000 MPa
Mean value of the tensile strength**	≥ 35 MPa
Glass transition temperature***	≥ 50 °C
Minimum workability time - at minimum installation temperature (10 °C) and maximum container size (5 kg) - at standard conditions (21 °C) and maximum container size (5 kg) - at maximum installation temperature (40 °C) and maximum container size (5 kg)	 180 min. 50 min. 20 min.
Minimum curing time - at minimum installation temperature (10 °C) - at standard conditions (21 °C) - at maximum installation temperature (40 °C)	 4 days 2 days 1 day

*According to EN ISO 9514:2019.
**According to EN ISO 527-1:2019, after 7 days of curing at standard conditions (21 °C, 50 % Rh).
***According to EN 12614:2004 after 7 days of curing at standard conditions (21 °C, 50 % Rh).

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Table C19.1 Bond strength of specimens cured at standard environmental conditions

Kit composition and layer structure			Bond strength [MPa]	Failure mode
Bonding agent FRS-BA, repair mortar FRS-PC 11, structural bonding agent FRS-CS, CFRP strip FRS-L-H	Single values	$f_{cti,surf}$	2,59	100% Cohesion*
			3,00	100% Cohesion*
			2,39	100% Cohesion*
			2,79	100% Cohesion*
			3,10	100% Cohesion*
	Mean value	$\boldsymbol{f_{ctm,surf}}$	**2,77**	-
	Characteristic value	$\boldsymbol{f_{ctk,surf}}$	**2,09**	-
Structural bonding agent FRS-CS, CFRP strip FRS-L-H	Single values	$f_{cti,surf}$	2,00	100% Cohesion*
			2,97	100% Cohesion*
			3,30	100% Cohesion*
			3,66	100% Cohesion*
			3,29	100% Cohesion*
	Mean value	$\boldsymbol{f_{ctm,surf}}$	**3,04**	-
	Characteristic value	$\boldsymbol{f_{ctk,surf}}$	**1,56**	-
Bonding agent FRS-BA, repair mortar FRS-PC 11, structural bonding agent FRS-CS, CFRP strip FRS-L-S	Single values	$f_{cti,surf}$	3,07	100% Cohesion*
			3,37	100% Cohesion*
			2,51	100% Cohesion*
			3,48	100% Cohesion*
			3,15	100% Cohesion*
	Mean value	$\boldsymbol{f_{ctm,surf}}$	**3,12**	-
	Characteristic value	$\boldsymbol{f_{ctk,surf}}$	**2,24**	-
Structural bonding agent FRS-CS, CFRP strip FRS-L-S	Single values	$f_{cti,surf}$	3,24	100% Cohesion*
			3,54	100% Cohesion*
			3,19	100% Cohesion*
			3,50	100% Cohesion*
			3,20	100% Cohesion*
	Mean value	$\boldsymbol{f_{ctm,surf}}$	**3,33**	-
	Characteristic value	$\boldsymbol{f_{ctk,surf}}$	**2,92**	-

Layer thicknesses:
Bonding agent for the repair mortar FRS-BA: 500-800 g/m²
Concrete repair mortar FRS-PC 11 $d_{M,max.}$: 30 mm
Structural bonding agent FRS-CS $d_{G,min.}$: 1 mm
CFRP strip FRS-L-S or FRS-L-H t_L: 1,4 mm

Curing time: 7 days f_{cm}: 50,5 MPa; f_{ck}: 49,0 MPa#
Curing temperature: 21 °C ± 2 °C

*100 % Cohesive failure in the concrete substrate. Reference concrete strength class C50/60.
#The characteristic values were calculated using the mean and standard deviation. 6 test specimens.

fischer C-Fiber Force Strengthening System

Annex C19

Performance
Bond strength of the C-Fiber Force Strengthening System to concrete cured at standard environmental conditions

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Table C20.1 Bond strength after low cycle fatigue action

Kit composition and layer structure			Bond strength [MPa]	Failure mode
Bonding agent FRS-BA, repair mortar FRS-PC 11, structural bonding agent FRS-CS, CFRP strip FRS-L-H	Single values	$f_{\mathrm{cti,surf,fat}}$	4,73 3,60 3,98 4,39 5,53	100% Cohesion* 100% Cohesion* 100% Cohesion* 100% Cohesion* 100% Cohesion*
	Mean value	$\boldsymbol{f_{\mathrm{ctm,surf,fat}}}$	**4,45****	-
($R_{\mathrm{fat,m}} = f_{\mathrm{ctm,surf,fat}} / f_{\mathrm{ctm,surf}}$)	**Characteristic value**	$\boldsymbol{f_{\mathrm{ctk,surf,fat}}}$	**2,72**	-
	Ratio	$\boldsymbol{R_{\mathrm{fat,m}}}$	**1,45**	-
Structural bonding agent FRS-CS, CFRP strip FRS-L-H	Single values	$f_{\mathrm{cti,surf,fat}}$	5,14 4,33 5,31 4,31 4,10	100% Cohesion* 100% Cohesion* 100% Cohesion* 100% Cohesion* 100% Cohesion*
	Mean value	$\boldsymbol{f_{\mathrm{ctm,surf,fat}}}$	**4,64****	-
	Characteristic value	$\boldsymbol{f_{\mathrm{ctk,surf,fat}}}$	**3,37**	-
($R_{\mathrm{fat,m}} = f_{\mathrm{ctm,surf,fat}} / f_{\mathrm{ctm,surf}}$)	**Ratio**	$\boldsymbol{R_{\mathrm{fat,m}}}$	**1,51**	-

Layer thicknesses:
Bonding agent for the repair mortar FRS-BA: 500 – 800 g/m²
Concrete repair mortar FRS-PC 11 $d_{\mathrm{M,max.}}$: 30 mm
Structural bonding agent FRS-CS $d_{G,\mathrm{min.}}$: 1 mm

Curing time: 7 days
Curing temperature: 21 °C ± 2 °C

f_{cm}: 50,5 MPa; f_{ck}: 49,0 MPa#

Exposure: 100,000 load cycles with an upper load of 3,32 kN (corresponds to 55 % of reference bond strength 3,07 MPa) and a lower load of 0,60 kN (corresponds to 10 % of reference bond strength 3,07 MPa).

*100 % Cohesive failure in the concrete substrate. Reference concrete according to EN 1542:1999, class C50/60.
**Reference bond strength of the unexposed reference member: $f_{\mathrm{ctm,surf}}$ = 3,07 MPa.
#The characteristic values were calculated using the mean and standard deviation. 6 test specimens.

fischer C-Fiber Force Strengthening System

Annex C20

Performance
Bond strength of the C-Fiber Force Strengthening System to concrete after low cycle fatigue action

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Table C21.1 Bond strength after long-term loading under harsh climatic conditions

Kit composition and layer structure			**Bond strength [MPa]**	**Failure mode**
Bonding agent FRS-BA, repair mortar FRS-PC 11, structural bonding agent FRS-CS, CFRP strip FRS-L-H	Single values	$f_{\mathrm{cti,surf,T_{min}}}$	4,64 4,97 5,64 4,56 4,77 5,30 5,10	100% Cohesion* 100% Cohesion* 100% Cohesion* 100% Cohesion* 100% Cohesion* 100% Cohesion* 100% Cohesion*
($R_{\mathrm{T_{min,m}}} = f_{\mathrm{ctm,surf,T_{min}}} / f_{\mathrm{ctm,surf}}$)	**Mean value**	$\boldsymbol{f_{\mathrm{ctm,surf,T_{min}}}}$	**5,00**	-
	Characteristic value	$\boldsymbol{f_{\mathrm{ctk,surf,T_{min}}}}$	**4,16**	-
	Ratio	$\boldsymbol{R_{\mathrm{T_{min,m}}}}$	**1,63****	-
Structural bonding agent FRS-CS, CFRP strip FRS-L-H	Single values	$\boldsymbol{f_{\mathrm{cti,surf,T_{min}}}}$	4,99 5,30 5,01 5,06 4,37 4,75 5,49	100% Cohesion* 100% Cohesion* 100% Cohesion* 100% Cohesion* 100% Cohesion* 100% Cohesion* 100% Cohesion*
($R_{\mathrm{T_{min,m}}} = f_{\mathrm{ctm,surf,T_{min}}} / f_{\mathrm{ctm,surf}}$)	**Mean value**	$\boldsymbol{f_{\mathrm{ctm,surf,,T_{min}}}}$	**5,00**	-
	Characteristic value	$\boldsymbol{f_{\mathrm{ctk,surf,T_{min}}}}$	**4,12**	-
	Ratio	$\boldsymbol{R_{\mathrm{T_{min,m}}}}$	**1,63****	-

Layer thicknesses:
Bonding agent for the repair mortar FRS-BA: 500-800 g/m²
Concrete repair mortar FRS-PC 11 $d_{\mathrm{M,max.}}$: 30 mm
Structural bonding agent FRS-CS $d_{G,\mathrm{min.}}$: 1 mm
CFRP strip FRS-L-H t_{L}: 1,4 mm

Curing time: 7 days
Curing temperature: 21 °C ± 2 °C

f_{cm}: 50,5 MPa; f_{ck}: 49,0 MPa#

Exposure: 183 days under sustained load corresponding to 20 % of $f_{\mathrm{ctm,surf}}$ (reference bond strength) at maximum temperature in use (40 °C) and ≥ 95 % relative humidity

*100 % Cohesive failure in the concrete substrate. Reference concrete according to EN 1542:1999, class C50/60.
**Surface tensile strength of the unexposed reference member: $f_{\mathrm{ctm,surf}}$ = 3,07 MPa.
#The characteristic values were calculated using the mean and standard deviation. 6 test specimens.

fischer C-Fiber Force Strengthening System

Annex C21

Performance
Bond strength of the C-Fiber Force Strengthening System to concrete after long-term loading under harsh climatic conditions

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Table C22.1 Bond strength of specimens cured at minimum temperature of installation				
Kit composition and layer structure			**Bond strength [MPa]**	**Failure mode**
Bonding agent FRS-BA, repair mortar FRS-PC 11, structural bonding agent FRS-CS, CFRP strip FRS-L-H	Single values	$f_{cti,surf,T_{min}}$	3,12 2,30 3,41 2,75 3,74	100% Cohesion* 100% Cohesion* 100% Cohesion* 100% Cohesion* 100% Cohesion*
	Mean value	$\boldsymbol{f_{ctm,surf,T_{min}}}$	**3,06**	-
	Characteristic value	$\boldsymbol{f_{ctk,surf,T_{min}}}$	**1,75**	-
($R_{T_{min,m}} = f_{ctm,surf,T_{min}} / f_{ctm,surf}$)	**Ratio**	$\boldsymbol{R_{T_{min,m}}}$	**1,01**	-
Structural bonding agent FRS-CS, CFRP strip FRS-L-H	Single values	$f_{cti,surf,T_{min}}$	3,55 3,04 3,55 3,95 3,66	100% Cohesion* 100% Cohesion* 100% Cohesion* 100% Cohesion* 100% Cohesion*
	Mean value	$\boldsymbol{f_{ctm,surf,T_{min}}}$	**3,55**	-
	Characteristic value	$\boldsymbol{f_{ctk,surf,T_{min}}}$	**2,78**	-
($R_{T_{min,m}} = f_{ctm,surf,T_{min}} / f_{ctm,surf}$)	**Ratio**	$\boldsymbol{R_{T_{min,m}}}$	**1,07**	-
Bonding agent FRS-BA, repair mortar FRS-PC 11, structural bonding agent FRS-CS, CFRP strip FRS-L-S	Single values	$f_{cti,surf,T_{min}}$	3,38 3,67 3,17 3,49 3,59	100% Cohesion* 100% Cohesion* 100% Cohesion* 100% Cohesion* 100% Cohesion*
	Mean value	$\boldsymbol{f_{ctm,surf,T_{min}}}$	**3,46**	-
	Characteristic value	$\boldsymbol{f_{ctk,surf,T_{min}}}$	**3,0**	-
($R_{T_{min,m}} = f_{ctm,surf,T_{min}} / f_{ctm,surf}$)	**Ratio**	$\boldsymbol{R_{T_{min,m}}}$	**1,25**	-
Structural bonding agent FRS-CS, CFRP strip FRS-L-S	Single values	$f_{cti,surf,T_{min}}$	3,70 3,58 3,78 3,78 3,68	100% Cohesion* 100% Cohesion* 100% Cohesion* 100% Cohesion* 100% Cohesion*
	Mean value	$\boldsymbol{f_{ctm,surf,T_{min}}}$	**3,71**	-
	Characteristic value	$\boldsymbol{f_{ctk,surf,T_{min}}}$	**3,51**	-
($R_{T_{min,m}} = f_{ctm,surf,T_{min}} / f_{ctm,surf}$)	**Ratio**	$\boldsymbol{R_{T_{min,m}}}$	**1,19**	-

Layer thicknesses:
Bonding agent for the repair mortar FRS-BA: 500-800 g/m²
Concrete repair mortar FRS-PC 11 $d_{M,max.}$: 30 mm
Structural bonding agent FRS-CS $d_{G,min.}$: 1 mm
CFRP strip FRS-L-S or FRS-L-H t_L: 1,4 mm

Curing time: 7 days
Curing temperature: 10 °C ± 2 °C

f_{cm}: 50,5 MPa; f_{ck}: 49,0 MPa#

*100 % Cohesive failure in the concrete substrate. Reference concrete according to EN 1542:1999, class C50/60.
#The characteristic values were calculated using the mean and standard deviation. 6 test specimens.

fischer C-Fiber Force Strengthening System

Annex C22

Performance
Bond strength of the C-Fiber Force Strengthening System to concrete cured at minimum installation temperature depending on the curing time

Table C23.1 Shear resistance of the anchorage of CFRP strips externally bonded to concrete (without repair mortar)

Type of the strip	Conc. comp. strength [MPa]	Conc. surf. tensile strength [MPa]	Ultimate anchorage load [kN]			Failure mode
FRS-L-H	C12/15⁺ f_{cm}: 18,6 f_{ck}: 14,1#	$f_{ctim,surf}$: 1,47 $f_{ctik,surf}$: 0,64	Single values	F_{bLi}	84,17 87,82	100% Cohesion* 100% Cohesion*
		$f_{ctim,surf}$: 1,59 $f_{ctik,surf}$: 1,30			80,23 104,62	100% Cohesion* 100% Cohesion*
		-	**Mean value**	$\boldsymbol{F_{bLm}}$	**89,21**	-
		-	**Characteristic value**	$\boldsymbol{F_{bLk}}$	**61,00**	-
FRS-L-H	C30/37⁺ f_{cm}: 33,2 f_{ck}: 29,7#	$f_{ctim,surf}$: 2,25 $f_{ctik,surf}$: 0,85	Single values	F_{bLi}	116,75 127,06	100% Cohesion* 100% Cohesion*
		$f_{ctim,surf}$: 1,81 $f_{ctik,surf}$: -**			93,95 104,57	100% Cohesion* 100% Cohesion*
		-	**Mean value**	$\boldsymbol{F_{bLm}}$	**110,58**	-
		-	**Characteristic value**	$\boldsymbol{F_{bLk}}$	**72,71**	-
FRS-L-H	C50/60⁺ f_{cm}: 47.6 f_{ck}: 42,3#	$f_{ctim,surf}$: 4,04 $f_{ctik,surf}$: 3,45	Single values	F_{bLi}	121,19 144,15	100% Cohesion* 100% Cohesion*
		$f_{ctim,surf}$: 2,10 $f_{ctik,surf}$: 1,47			119,59 118,37	100% Cohesion* 100% Cohesion*
		-	**Mean value**	$\boldsymbol{F_{bLm}}$	**125,83**	-
		-	**Characteristic value**	$\boldsymbol{F_{bLk}}$	**93,56**	-
FRS-L-S	C12/15⁺ f_{cm}: 18,6 f_{ck}: 14,1#	$f_{ctim,surf}$: 2,26 $f_{ctik,surf}$: 1,12	Single values	F_{bLi}	83,11 92,37	100% Cohesion* 100% Cohesion*
		$f_{ctim,surf}$: 1,10 $f_{ctik,surf}$: -**			85,95 92,35	100% Cohesion* 100% Cohesion*
		-	**Mean value**	$\boldsymbol{F_{bLm}}$	**88,45**	-
		-	**Characteristic value**	$\boldsymbol{F_{bLk}}$	**76,17**	-
FRS-L-S	C30/37⁺ f_{cm}: 33,2 f_{ck}: 29,7#	$f_{ctim,surf}$: 2,45 $f_{ctik,surf}$: 0,85	Single values	F_{bLi}	109,49 134,98	100% Cohesion* 100% Cohesion*
		$f_{ctim,surf}$: 2,10 $f_{ctik,surf}$: 1,10			102,60 111,04	100% Cohesion* 100% Cohesion*
		-	**Mean value**	$\boldsymbol{F_{bLm}}$	**114,53**	-
		-	**Characteristic value**	$\boldsymbol{F_{bLk}}$	**77,39**	-
FRS-L-S	C50/60⁺ f_{cm}: 47.6 f_{ck}: 42,3#	$f_{ctim,surf}$: 3,80 $f_{ctik,surf}$: 2,69	Single values	F_{bLi}	112,53 119,29	100% Cohesion* 100% Cohesion*
		$f_{ctim,surf}$: 2,57 $f_{ctik,surf}$: 1,31			105,01 106,34	100% Cohesion* 100% Cohesion*
		-	**Mean value**	$\boldsymbol{F_{bLm}}$	**110,79**	-
		-	**Characteristic value**	$\boldsymbol{F_{bLk}}$	**93,58**	-

Bond length l_v of CFRP strip: 1000 mm
Layer thickness of the structural bonding agent FRS-CS $d_{G,min.}$: 1 mm
Thickness of CFRP strips FRS-L-S or FRS-L-H t_L: 1,4 mm
Width of the CFRP strip b_L: 100 mm
*100 % cohesion failure in the concrete.
#The characteristic values were calculated using the mean and standard deviation. 6 test specimens.
⁺target concrete strength class, f_{cm} and f_{ck} represent the determined strength values.

fischer C-Fiber Force Strengthening System

Annex C23

Performance
Shear resistance of the anchorage of FRS-L-H and FRS-L-S CFRP strips externally bonded to concrete (without repair mortar)

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Shear resistance of the anchorage of CFRP strips externally bonded to concrete (without repair mortar)

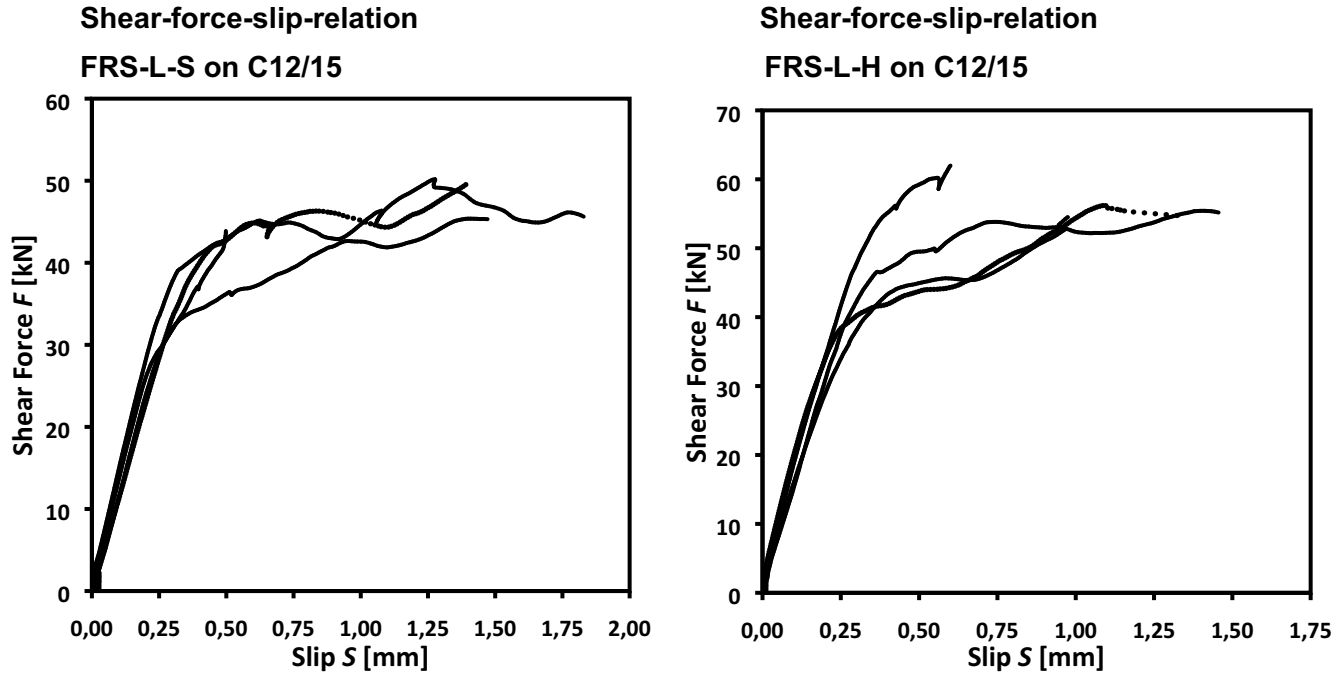

Figure C24.1: Shear force-slip curves of shear resistance measurements of the anchorage of FRS-L-S and FRS-L-H CFRP strips externally bonded to concrete of class C12/15.

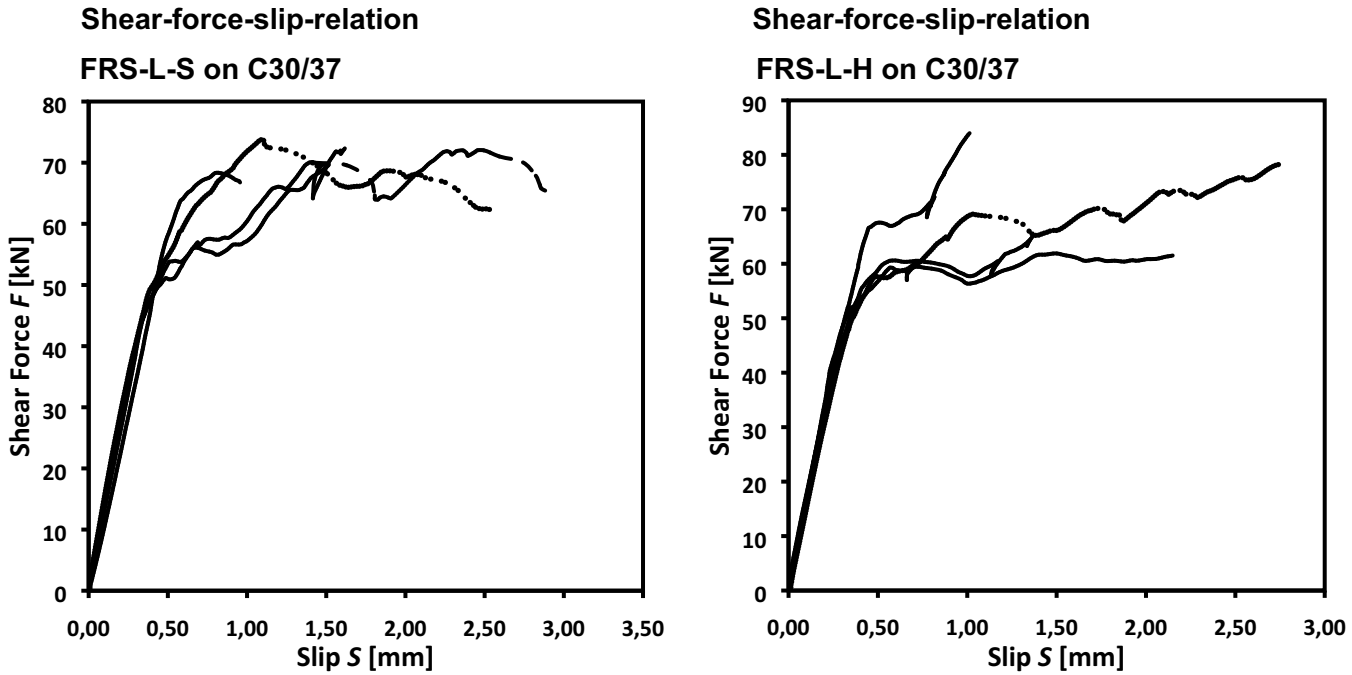

Figure C24.2: Shear-force-slip curves of shear resistance measurements of the anchorage of FRS-L-S and FRS-L-H CFRP strips externally bonded to concrete of class C30/37.

fischer C-Fiber Force Strengthening System	**Annex C24**
Performance Shear resistance of the anchorage of FRS-L-H and FRS-L-S CFRP strips externally bonded to concrete (without repair mortar)	

Shear resistance of the anchorage of CFRP strips externally bonded to concrete (without repair mortar)

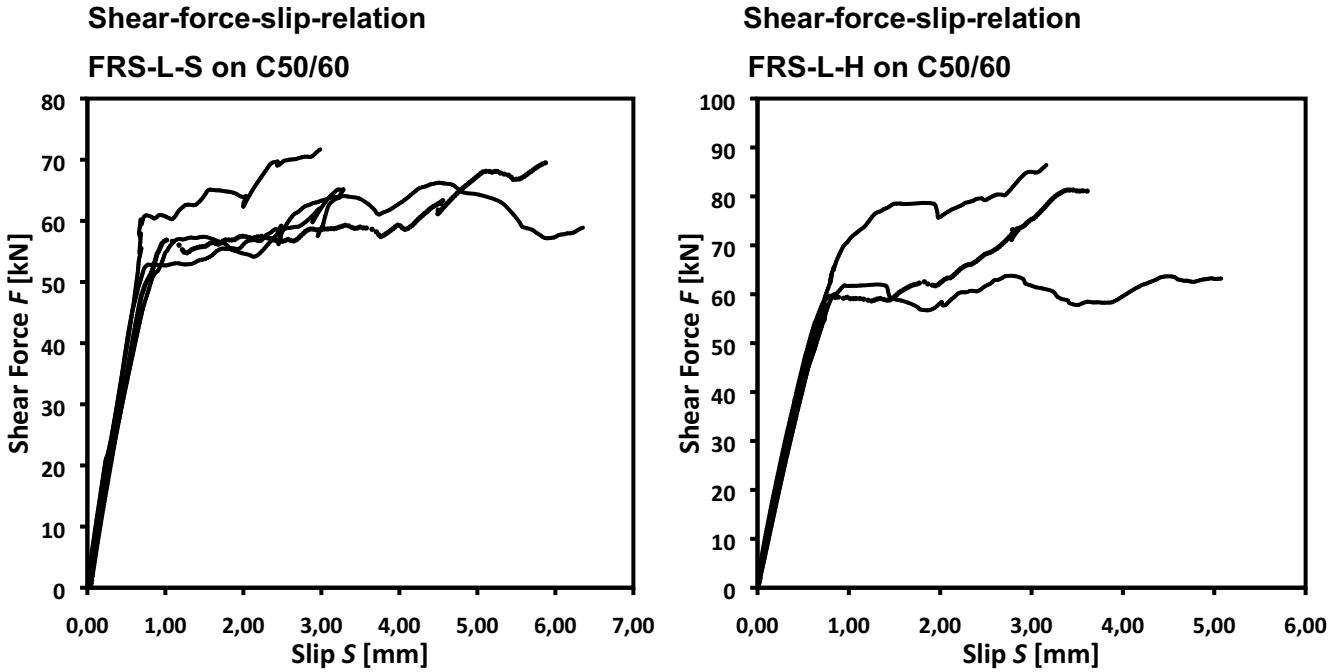

Figure C25.1: Shear-force-slip curves of shear resistance measurements of the anchorage of FRS-L-S and FRS-L-H CFRP strips externally bonded to concrete of class C50/60.

fischer C-Fiber Force Strengthening System	**Annex C25**
Performance Shear resistance of the anchorage of FRS-L-H and FRS-L-S CFRP strips externally bonded to concrete (without repair mortar)	

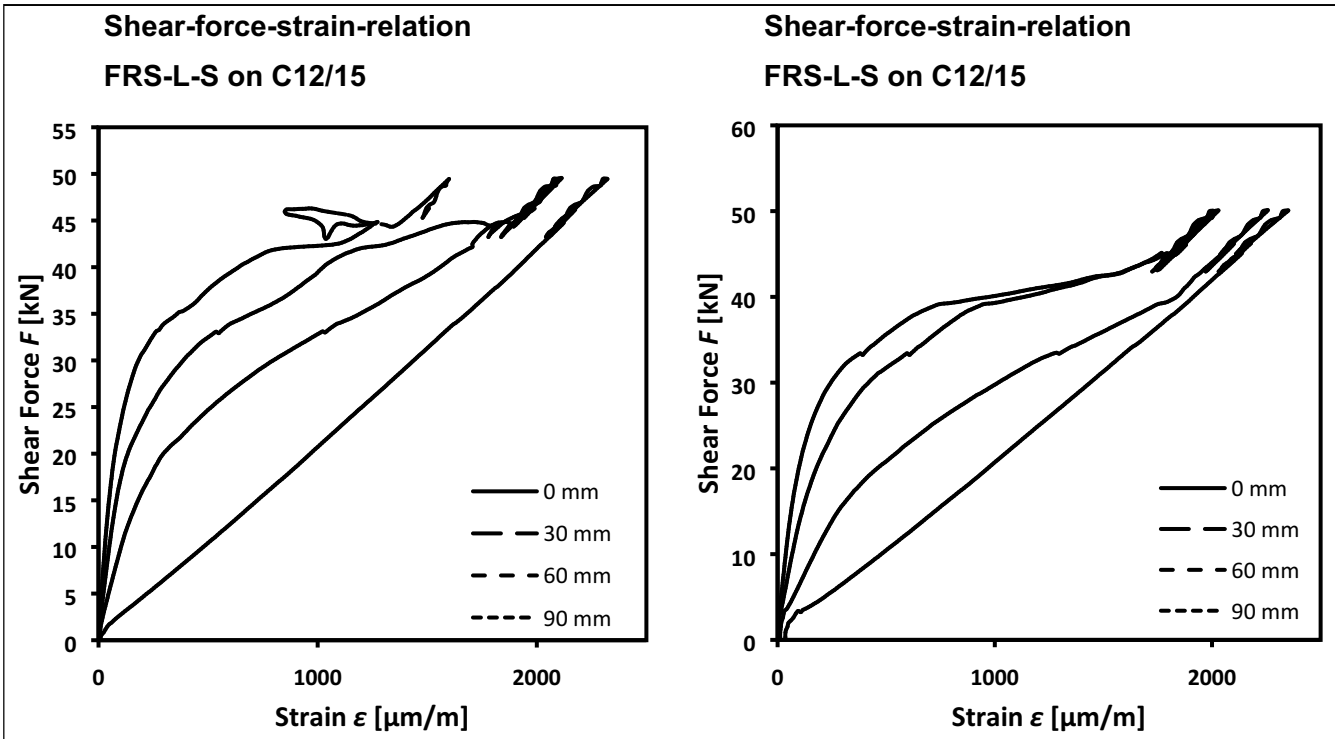

Figure C26.1: Shear-force-strain curves of shear resistance measurements of the anchorage of FRS-L-S CFRP strips externally bonded to concrete of class C12/15 along the bond length. Strain measurement at 0, 30, 60, 90 mm distances from the load application point.

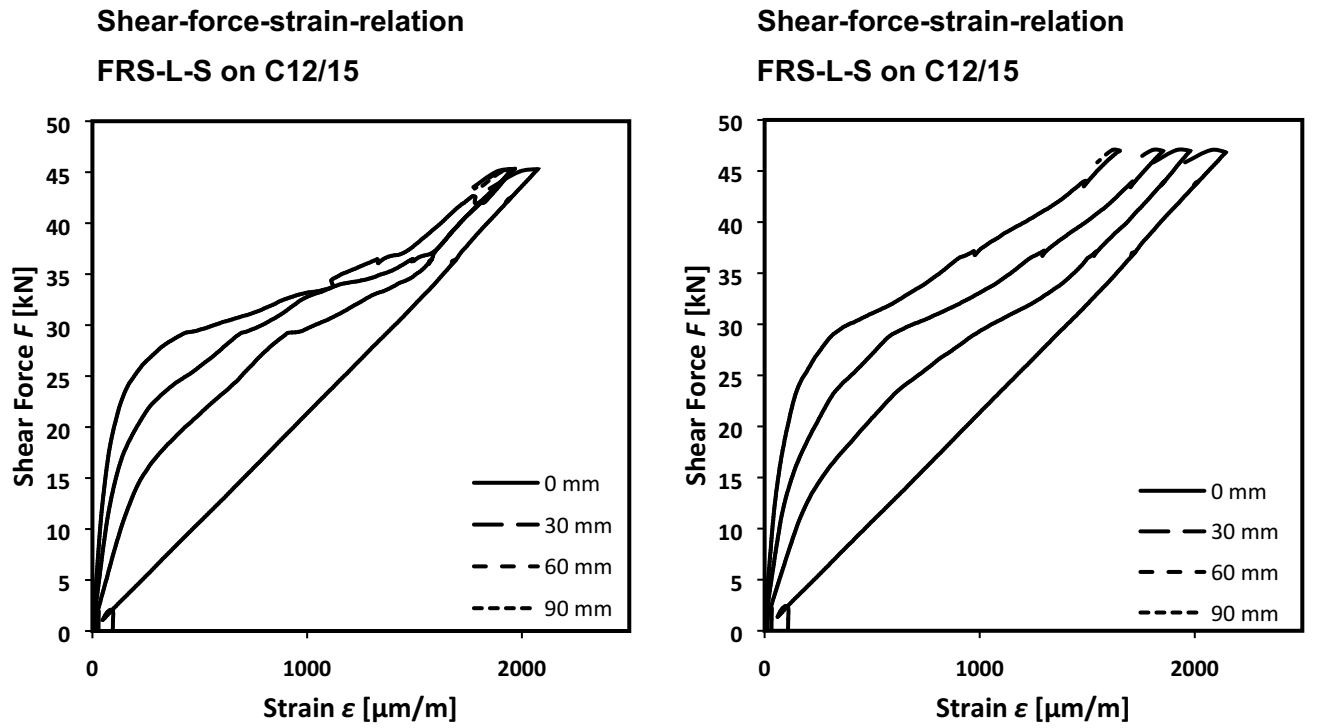

Figure C26.2: Shear-force-Strain curves of shear resistance measurements of the anchorage of FRS-L-S CFRP strips externally bonded to concrete of class C12/15 along the bond length. Strain measurement at 0, 30, 60, 90 mm distances from the load application point.

fischer C-Fiber Force Strengthening System	**Annex C26**
Performance Shear resistance of the anchorage of FRS-L-S CFRP strips externally bonded to concrete (without repair mortar)	

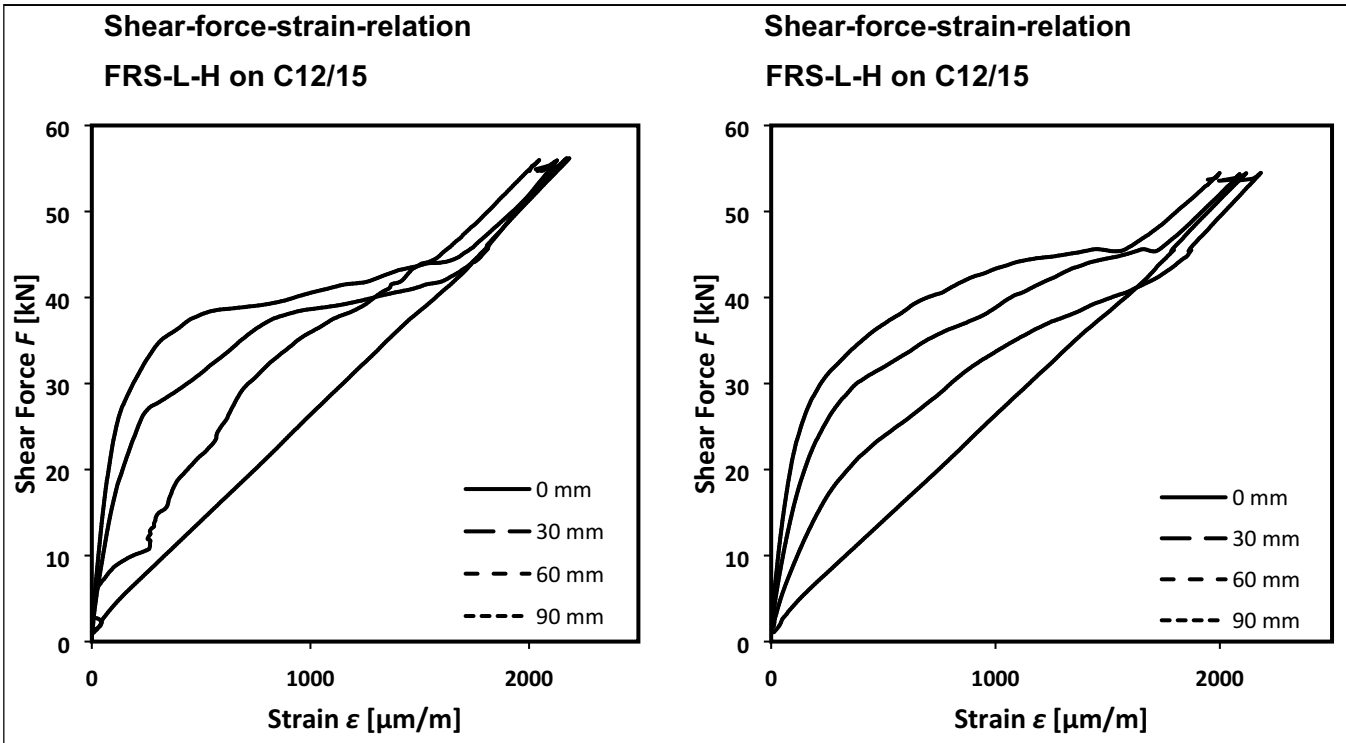

Figure C27.1: Shear-force-strain curves of shear resistance measurements of the anchorage of FRS-L-H CFRP strips externally bonded to concrete of class C12/15 along the bond length. Strain measurement at 0, 30, 60, 90 mm distances from the load application point.

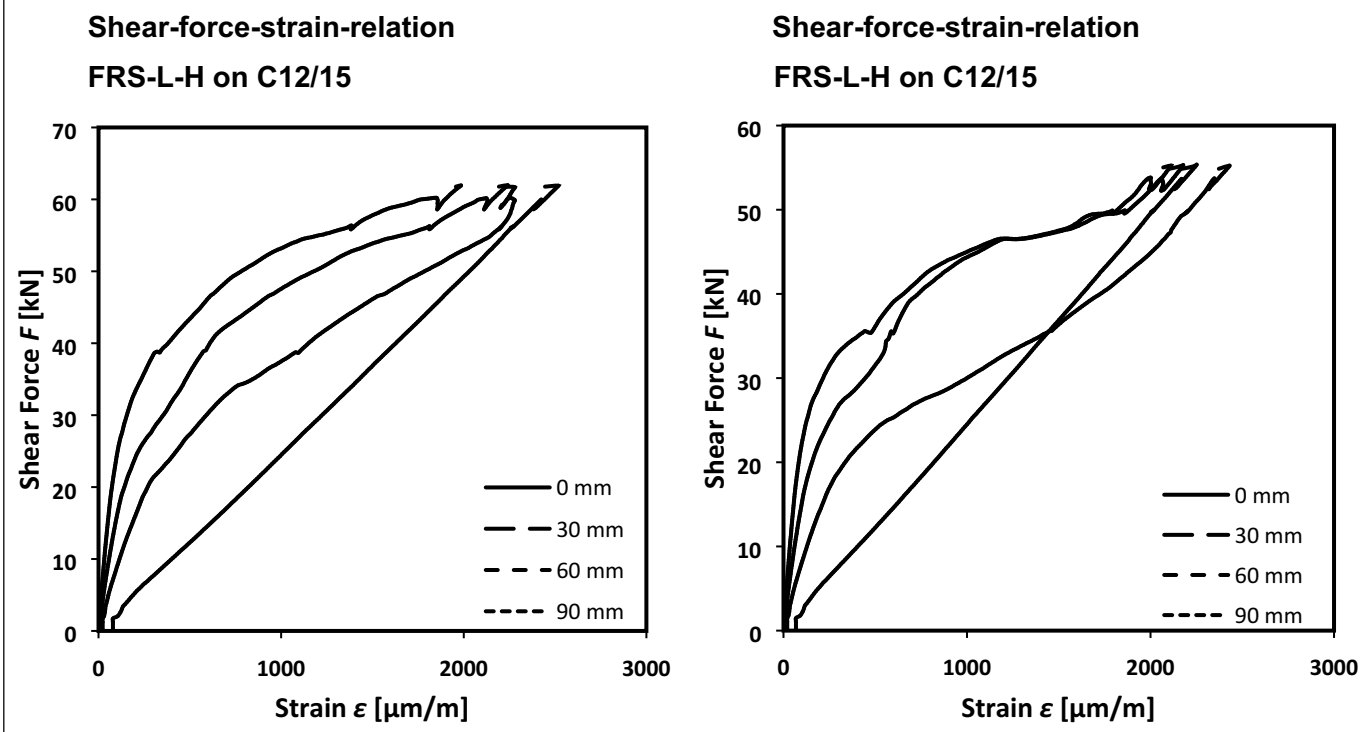

Figure C27.2: Shear-force-strain curves of shear resistance measurements of the anchorage of FRS-L-H CFRP strips externally bonded to concrete of class C12/15 along the bond length. Strain measurement at 0, 30, 60, 90 mm distances from the load application point.

fischer C-Fiber Force Strengthening System	**Annex C27**
Performance Shear resistance of the anchorage of FRS-L-H CFRP strips externally bonded to concrete (without repair mortar). Evaluation of the strains along the load application zone.	

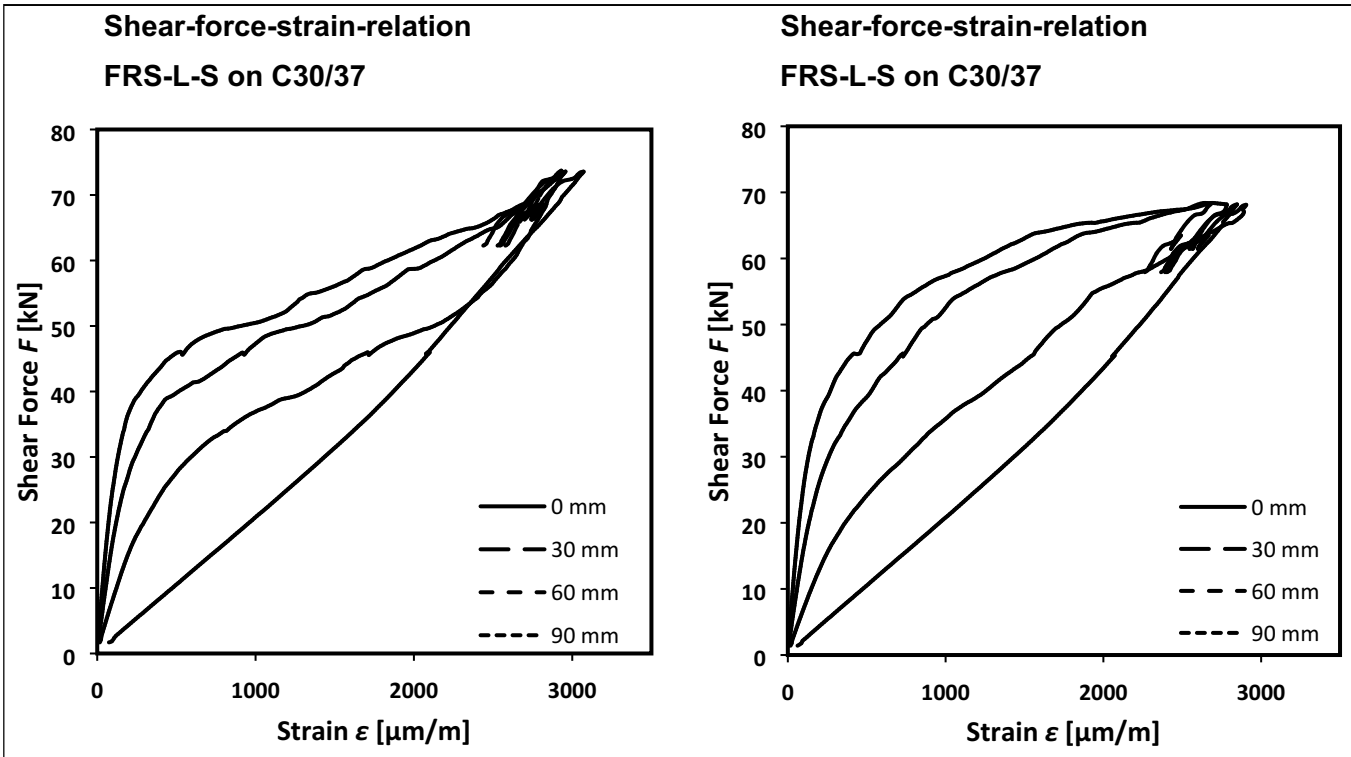

Figure C28.1: Shear-force-strain curves of shear resistance measurements of the anchorage of FRS-L-S CFRP strips externally bonded to concrete of class C30/37 along the bond length. Strain measurement at 0, 30, 60, 90 mm distances from the load application point.

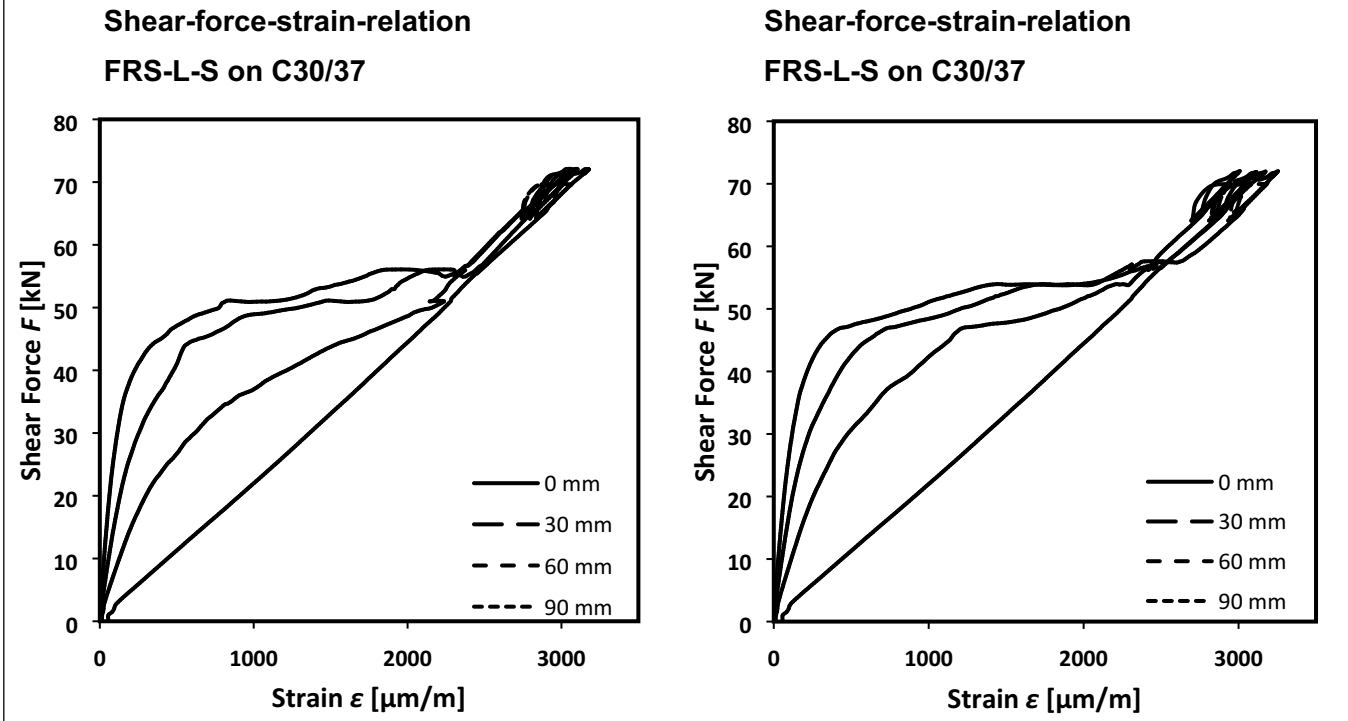

Figure C28.2: Shear-force-strain of shear resistance measurements of the anchorage of FRS-L-S CFRP strips externally bonded to concrete of class C30/37 along the bond length. Strain measurement at 0, 30, 60, 90 mm distances from the load application point.

fischer C-Fiber Force Strengthening System	**Annex C28**
Performance Shear resistance of the anchorage of FRS-L-S CFRP strips externally bonded to concrete, Evaluation of the strain in the load introduction zone	

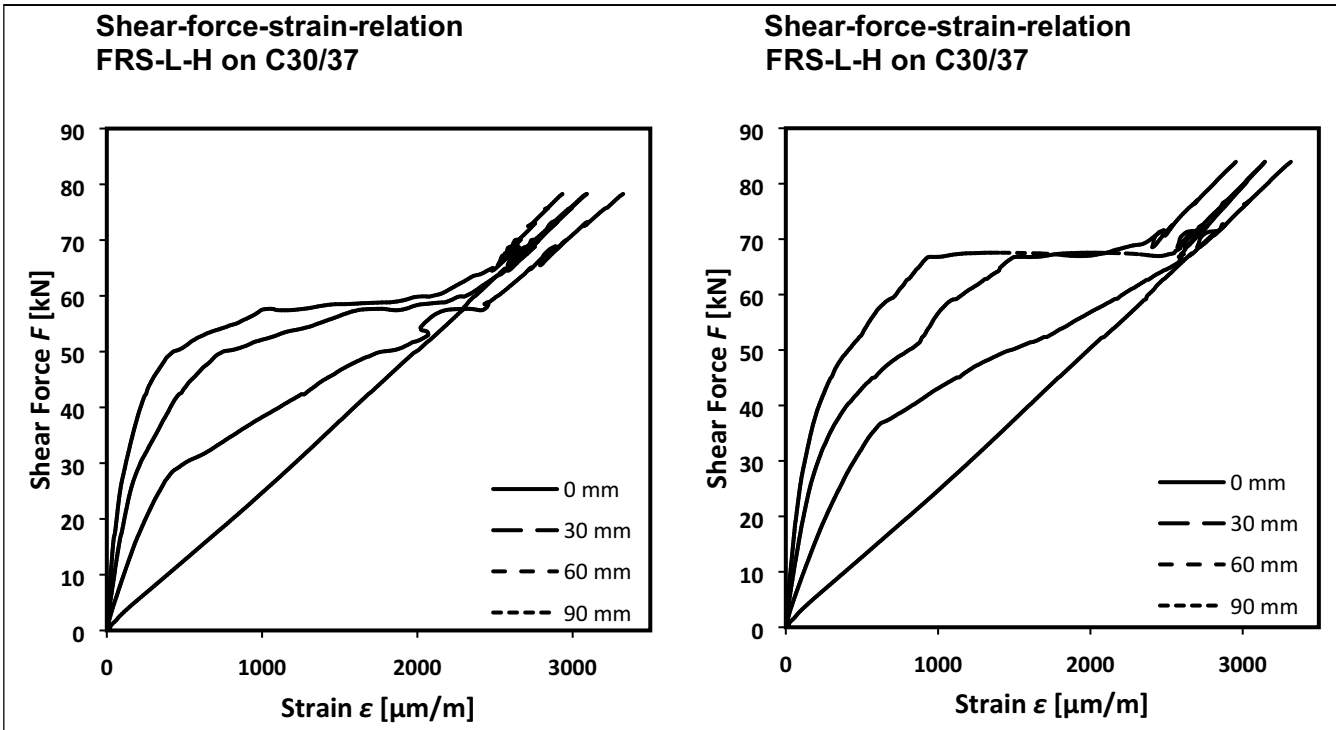

Figure C29.1: Shear-force-strain curves of shear resistance measurements of the anchorage of FRS-L-H CFRP strips externally bonded to concrete of class C30/37 along the bond length. Strain measurement at 0, 30, 60, 90 mm distances from the load application point.

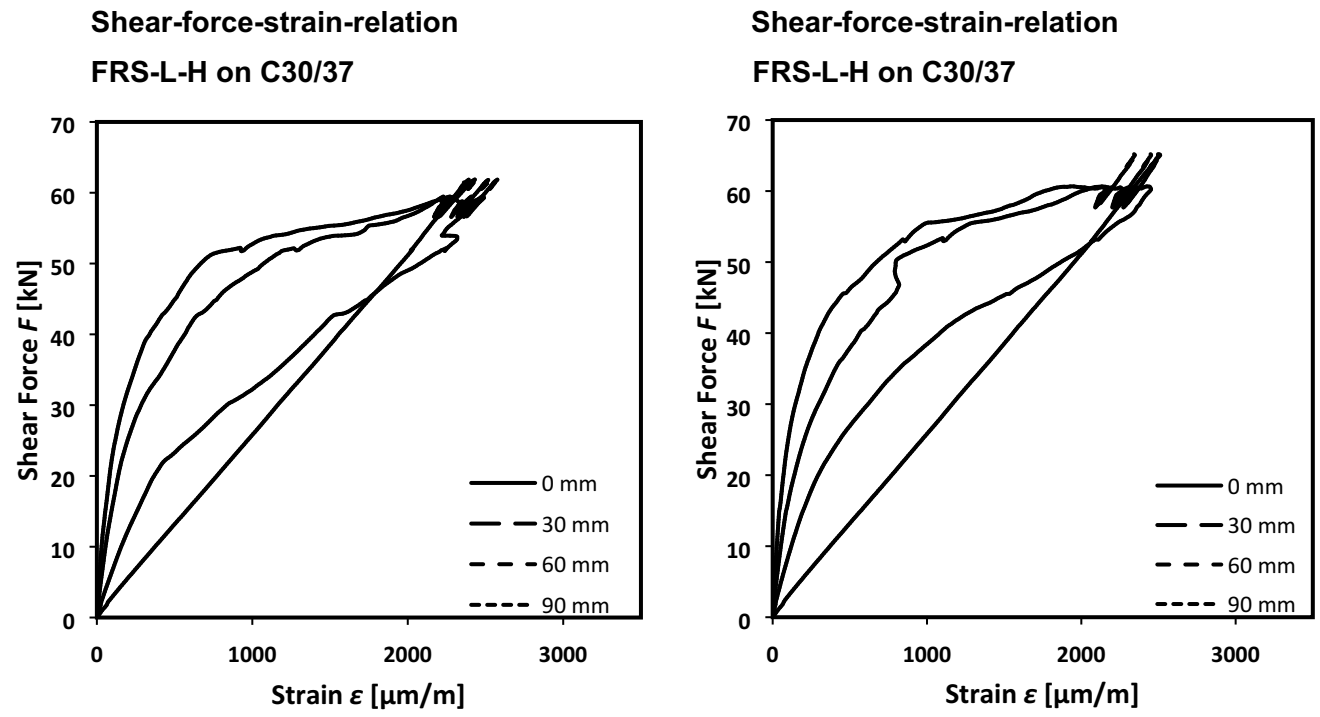

Figure C29.2: Shear-force-strain curves of shear resistance measurements of the anchorage of FRS-L-H CFRP strips externally bonded to concrete of class C30/37 along the bond length. Strain measurement at 0, 30, 60, 90 mm distances from the load application point.

fischer C-Fiber Force Strengthening System	**Annex C29**
Performance Shear resistance of the anchorage of FRS-L-H CFRP strips externally bonded to concrete (without repair mortar). Evaluation of the strains along the load application zone	

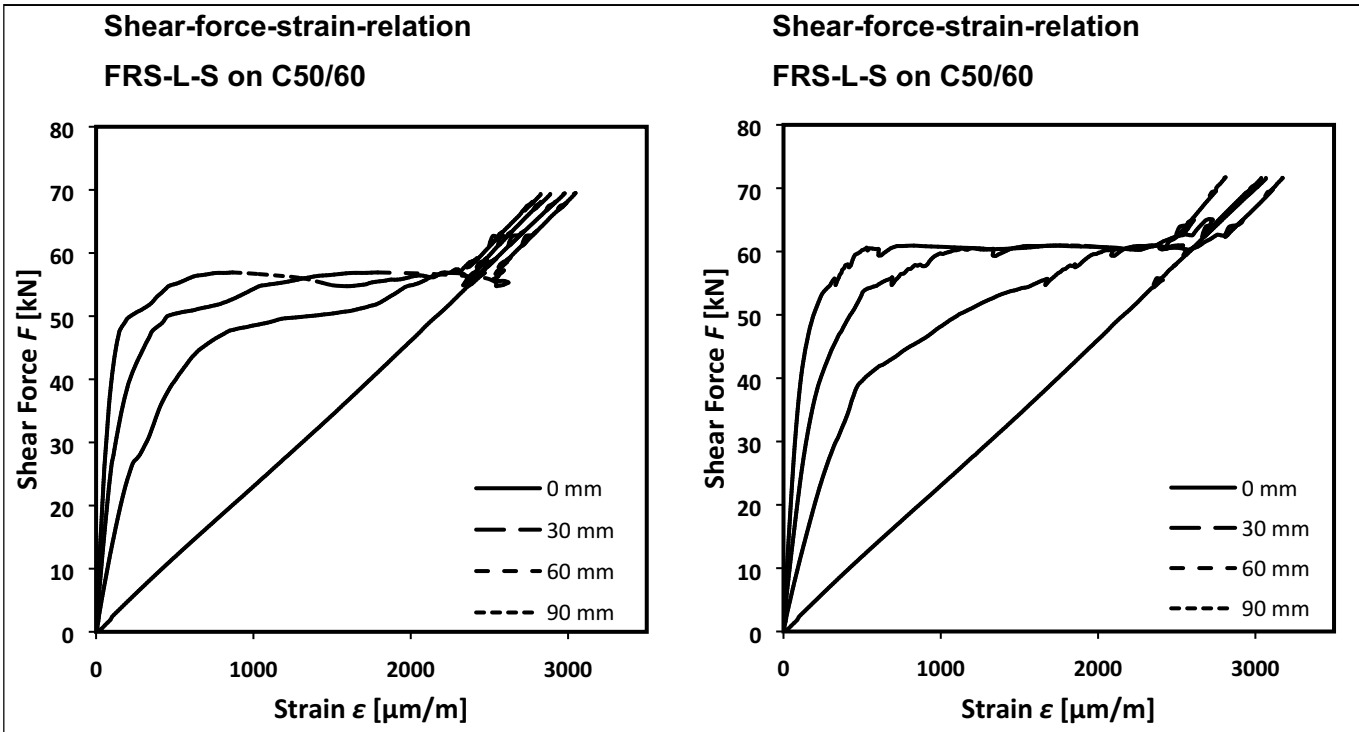

Figure C30.1: Shear-force-strain curves of shear resistance measurements of the anchorage of FRS-L-S CFRP strips externally bonded to concrete of class C50/60 along the bond length. Strain measurement at 0, 30, 60, 90 mm distances from the load application point.

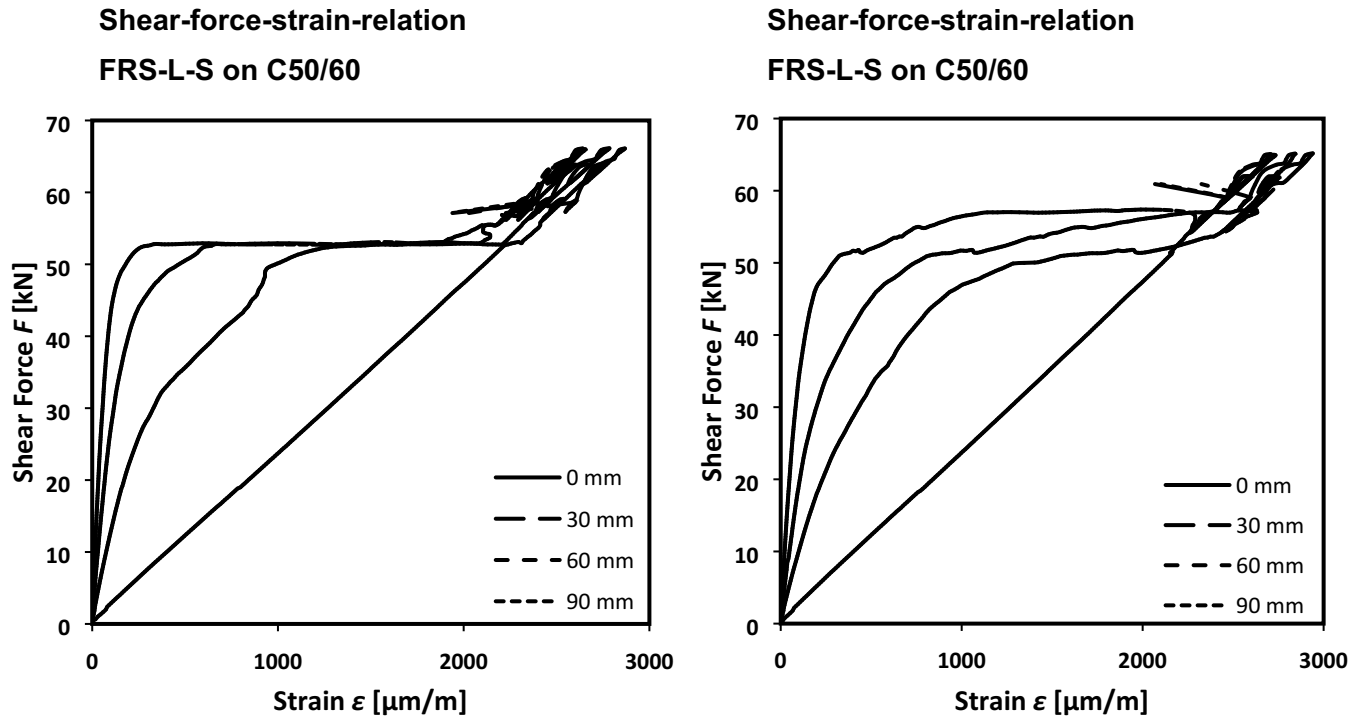

Figure C30.2: Shear-force-strain curves of shear resistance measurements of the anchorage of FRS-L-S CFRP strips externally bonded to concrete of class C50/60 along the bond length. Strain measurement at 0, 30, 60, 90 mm distances from the load application point.

fischer C-Fiber Force Strengthening System	**Annex C30**
Performance Shear resistance of the anchorage of FRS-L-S CFRP strips externally bonded to concrete (without repair mortar). Evaluation of the strains along the load application zone	

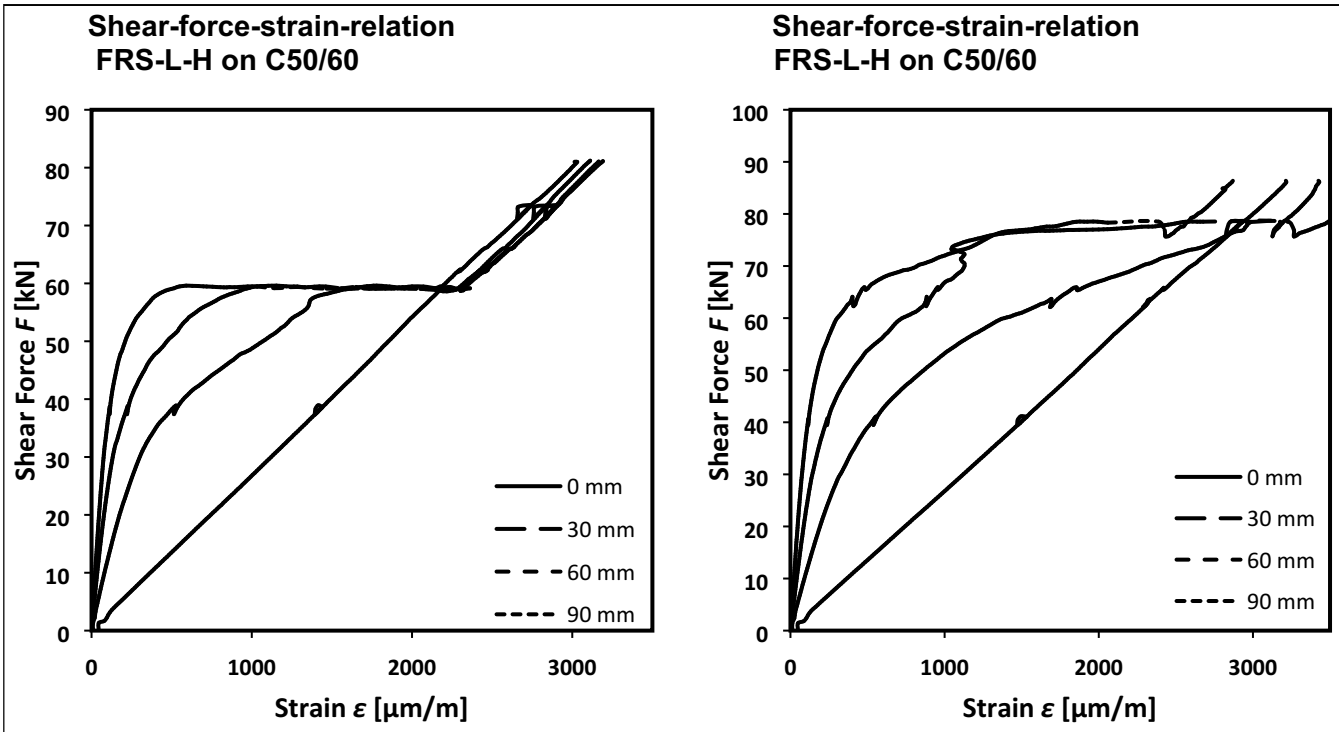

Figure C31.1: Shear-force-strain curves of shear resistance measurements of the anchorage of FRS-L-H CFRP strips externally bonded to concrete of class C50/60 along the bond length. Strain measurement at 0, 30, 60, 90 mm distances from the load application point.

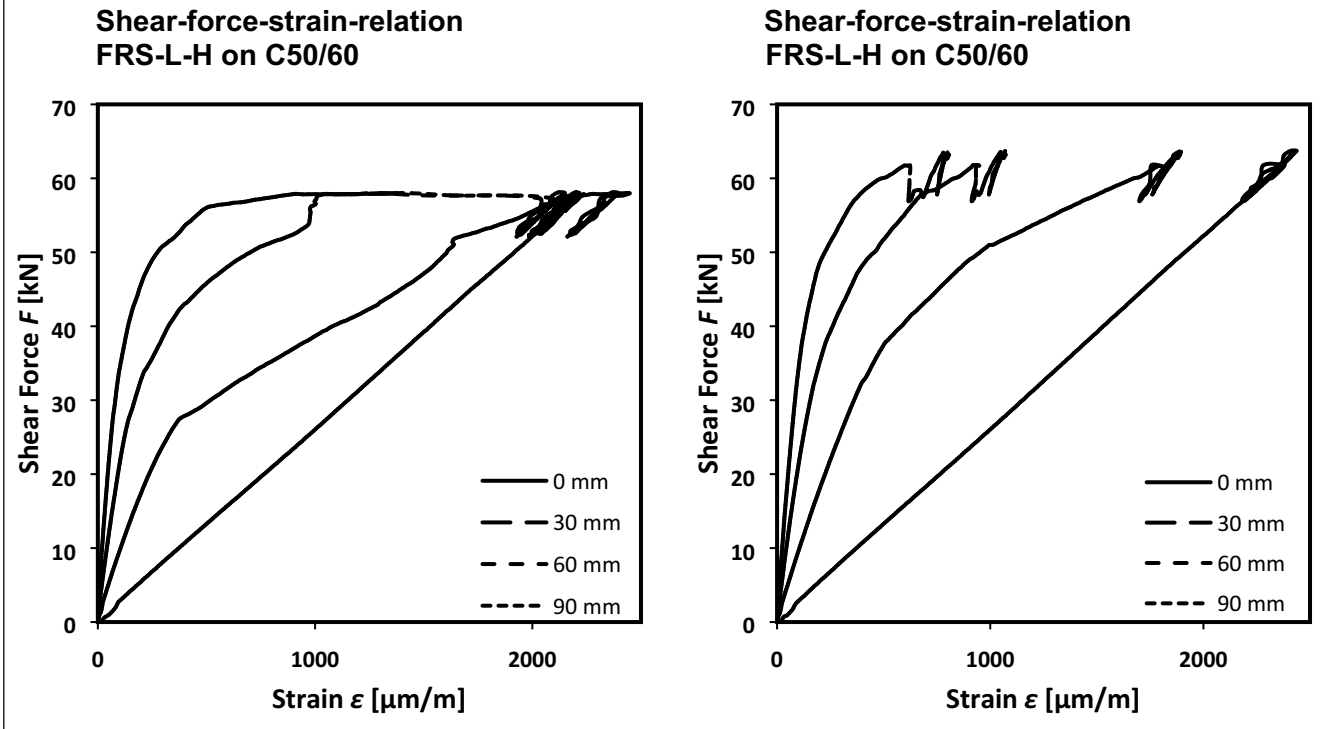

Figure C31.2: Shear-force-strain curves of shear resistance measurements of the anchorage of FRS-L-H CFRP strips externally bonded to concrete of class C50/60 along the bond length. Strain measurement at 0, 30, 60, 90 mm distances from the load application point.

fischer C-Fiber Force Strengthening System	**Annex C31**
Performance Shear resistance of the anchorage of FRS-L-S CFRP strips externally bonded to concrete (without repair mortar). Evaluation of the strains along the load application zone	

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Table C32.1 Fatigue behaviour of the anchorage of CFRP strips externally bonded to concrete

Load levels	Conc. comp. strength [MPa]	Conc. surf. tensile strength [MPa]	Lower and upper bound loads [kN]	Number of cycles
A1 (Test 1)	C12/15+	$f_{ctm,surf}$: 1,25	F^{l}_{bLi}: 12,33; F^{u}_{bLi}: 36,99; ΔF_{bLi}: 24,66	2 000 000 (P)
A2 (Test 1)	f_{cm}: 18,6	$f_{ctik,surf}$: 0,75	F^{l}_{bLi}: 12,33; F^{u}_{bLi}: 40,28; ΔF_{bLi}: 27,95	2 000 000 (P)
B1 (Test 2)	f_{ck}: 14,1#	$f_{ctm,surf}$: 1,44	F^{l}_{bLi}: 24,66; F^{u}_{bLi}: 45,21; ΔF_{bLi}: 20,55	2 000 000 (P)
B2 (Test 2)		$f_{ctik,surf}$: 1,27	F^{l}_{bLi}: 24,66; F^{u}_{bLi}: 47,68; ΔF_{bLi}: 23,02	2 000 000 (P)
B3 (Test 2)			F^{l}_{bLi}: 24,66; F^{u}_{bLi}: 50,14; ΔF_{bLi}: 25,48	1 017 013 (F)
B4 (Test 2)			F^{l}_{bLi}: 24,66; F^{u}_{bLi}: 52,61; ΔF_{bLi}: 27,47	72,388 (F)
C1 (Test 3)		$f_{ctm,surf}$: 1,60	F^{l}_{bLi}: 36,99; F^{u}_{bLi}: 52,61; ΔF_{bLi}: 15,62	2 000 000 (F)
C3 (Test 3)		$f_{ctik,surf}$: 0,42	F^{l}_{bLi}: 36,99; F^{u}_{bLi}: 57,42; ΔF_{bLi}: 20,43	129 633 (F)
D1 (Test 4)		$f_{ctm,surf}$: 1,40	F^{l}_{bLi}: 49,32; F^{u}_{bLi}: 60,83; ΔF_{bLi}: 11,51	2 000 000 (P)
D2 (Test 4)		$f_{ctik,surf}$: 0,67	F^{l}_{bLi}: 49,32; F^{u}_{bLi}: 62,47; ΔF_{bLi}: 13,15	1 051 239 (F)
A1 (Test 5)	C30/37+	$f_{ctm,surf}$: 2,31	F^{l}_{bLi}: 15,80; F^{u}_{bLi}: 47,41; ΔF_{bLi}: 31,61	2 000 000 (P)
A2 (Test 5)	f_{cm}: 33,2	$f_{ctik,surf}$: 1,36	F^{l}_{bLi}: 15,80; F^{u}_{bLi}: 51,62; ΔF_{bLi}: 35,82	2 000 000 (P)
A3 (Test 5)	f_{ck}: 29,7#		F^{l}_{bLi}: 15,80; F^{u}_{bLi}: 55,84; ΔF_{bLi}: 40,04	247 343 (F)
A4 (Test 5)			F^{l}_{bLi}: 15,80; F^{u}_{bLi}: 60,05; ΔF_{bLi}: 44,25	299 050 (F)
C1 (Test 6)		$f_{ctm,surf}$: 2,73	F^{l}_{bLi}: 47,41; F^{u}_{bLi}: 67,42; ΔF_{bLi}20,01	2 000 000 (P)
C2 (Test 6)		$f_{ctik,surf}$: 2,15	F^{l}_{bLi}: 47,41; F^{u}_{bLi}: 70,58; ΔF_{bLi}: 23,17	720 000 (F)
C3 (Test 6)			F^{l}_{bLi}: 47,41; F^{u}_{bLi}: 73,75; ΔF_{bLi}: 26,34	129 631 (F)
A1 (Test 7)	C50/60+	$f_{ctm,surf}$: 3,23	F^{l}_{bLi}: 18,06; F^{u}_{bLi}: 54,18; ΔF_{bLi}: 36,12	2 000 000 (P)
A2 (Test 7)	f_{cm}: 47,6	$f_{ctik,surf}$: 1,31	F^{l}_{bLi}: 18,06; F^{u}_{bLi}: 58,99; ΔF_{bLi}: 40,93	2 000 000 (P)
A3 (Test 7)	f_{ck}: 42,3#		F^{l}_{bLi}: 18,06; F^{u}_{bLi}: 63,81; ΔF_{bLi}: 45,75	1 339 552 (F)
A4 (Test 7)			F^{l}_{bLi}: 18,06; F^{u}_{bLi}: 68,62; ΔF_{bLi}: 50,56	346 523 (F)
D1 (Test 8)		$f_{ctm,surf}$: 3,10	F^{l}_{bLi}: 72,73; F^{u}_{bLi}: 89,09; ΔF_{bLi}: 16,86	2 000 000 (F)
		$f_{ctik,surf}$: -*		

Bond length l_v of CFRP strip: 1000 mm
Layer thickness of the structural bonding agent FRS-CS $d_{G,min.}$: 1 mm
Thickness of CFRP strips FRS-L-S or FRS-L-H t_L: 1,4 mm
Width of the CFRP strip b_L: 100 mm
*100 % cohesive failure in the concrete substrate.
** not available.

(P): No damage in the bonded area detected (< 30 mm debonding)
(F): Damage in the bonded area detected (≥ 30 mm debonding)

*Not determinable: The evaluation of the characteristic value based on EN 1990:2002+A1:2005+A1:2005/AC: 2010 provides a negative result.
#The characteristic values were calculated using the mean and standard deviation. 6 test specimens.
+target concrete strength class, f_{cm} and f_{ck} represent the determined strength values.

fischer C-Fiber Force Strengthening System

Performance
Fatigue behaviour of the anchorage of FRS-L-H CFRP strips externally bonded to concrete

Annex C32

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Table C33.1 Ultimate anchorage load of near surface mounted CFRP strips

Concrete grade	Bond length l_{bl} [mm]	Edge distance a_r [mm]	Ultimate load [kN]					Type of Fracture
C12/15	300	30	Single values	Test No.	4.1**	F_{bLi}	19,28	A*
					4.2		18,05	B, A*
					4.3		20,16	B, A*
			Mean value			$\boldsymbol{F_{bLm}}$	**19,16**	
			Characteristic value			$\boldsymbol{F_{bLk}}$	**15,60**	
C12/15	300	150	Single values	Test No.	5.1	F_{bLi}	29,43	B*
					5.2**		30,51	B*
					5.3		24,17	B*
			Mean value			$\boldsymbol{F_{bLm}}$	**28,04**	-
			Characteristic value			$\boldsymbol{F_{bLk}}$	**16,61**	-
C50/60	100	150	Single values	Test No.	2.1	F_{bLi}	24,69	B*
					2.2		23,16	B*
					2.3**		28,59	B*
			Mean value			$\boldsymbol{F_{bLm}}$	**25,48**	-
			Characteristic value			$\boldsymbol{F_{bLk}}$	**16,04**	-
C50/60	300	30	Single values	Test No.	3.1	F_{bLi}	26,00	B, L*
					3.2		30,82	B, L*
					3.3		29,85	B, L*
			Mean value			$\boldsymbol{F_{bLm}}$	**28,89**	-
			Characteristic value			$\boldsymbol{F_{bLk}}$	**20,31**	-
C50/60	300	150	Single values	Test No.	1.1	F_{bLi}	25,34	B*
					1.2**		28,81	B*
					1.3**		35,00	B*
			Mean value			$\boldsymbol{F_{bLm}}$	**29,72**	-
			Characteristic value			$\boldsymbol{F_{bLk}}$	**13,23**	-

Concrete strength:
f_{cm}: 20,3 MPa; f_{ck}: 19,0 MPa# (C12/15+)
f_{cm}: 48,1 MPa; f_{ck}: 46,8 MPa# (C50/60+)

Installation parameters:
Width of the slot b_s: 3.7 – 4,2 mm
Depth of the slots t_s: 13 mm
21 °C, 50 Rh, cured for 7 days

Type and geometry of the CFRP strips:
FRS-L-S NSM 10 × 1,7 mm

Characteristics of the CFRP strips and structural bonding agent:
FRS-L-S NSM: E_{Lm}: 173 GPa ; f_{Lm}: 3054 MPa; W_{fi}: 77,4 %
FRS-CS: f_{Gflm}: 31,6 MPa ; f_{Gflk}: 24,0 MPa
f_{Gcm}: 89,4 MPa ; f_{Gck}: 87,0 MPa

*Type of failure: A ≙ Cohesive failure in the concrete substrate;
B ≙ Cohesive failure in the adhesive;
L ≙ Tensile failure of the CFRP strip

**Recalculation of the slip from the fiber optic strain measurement not possible.
#The characteristic values were calculated using the mean and standard deviation. 6 test specimens.
+target concrete strength class, f_{cm} and f_{ck} represent the determined strength values.

fischer C-Fiber Force Strengthening System

Annex C33

Performance
Ultimate anchorage load of near surface mounted FRS-L-S NSM CFRP strips

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Table C34.1 Reaction to fire of the applied kit

Kit assembly and layer structure	Substrate used for testing	Performance in accordance with DIN EN 13501-1
Bonding agent FRS-BA, repair mortar FRS-PC 11, structural bonding agent FRS-CS, CFRP strip FRS-L-S 100 mm × 1,4 mm	Calcium silicate board* (10 mm thick plate)	Class E**

The fischer C-Fiber Force Strengthening System is classified as “class E” in accordance DIN EN 13501-1 if applied as a kit within the field of application covered by this ETA on any substrate of “class A2-s1, d0” or class A1, with a density of ≥ 650 kg/m³ in accordance with EN 13238:2010-06 section 5.3.2.1 and 5.3.2.2, and with the following layer thicknesses or below:

Maximum layer thicknesses classified:

Bonding agent for the repair mortar FRS-BA: ≤ 800 g/m²
Concrete repair mortar FRS-PC 11 $d_{\mathrm{M,max.}}$: ≤ 30 mm
Structural bonding agent FRS-CS $d_{\mathrm{G,max.}}$: ≤ 5 mm
CFRP laminate FRS-L-S or FRS-L-H t_{l}: ≤ 1,4 mm
Without any additional surface coating or suchlike applied after execution of the kit.

*Standard substrate in accordance with DIN EN 13238

**In case of near surface mounted application with CFRP laminate "FRS-L-S NSM", the classification remains valid also for CFRP laminates of the higher thickness t_{L} ≤ 1,7 mm.

fischer C-Fiber Force Strengthening System

Performance
Reaction to fire of the applied kit

Annex C34