Sika® FRCM Systems
System Properties and Design Values

24.10.2023 / VERSION 1.1 / SIKA® LIMITED / ROB DOHERTY

BUILDING TRUST

TABLE OF CONTENTS

1	**SCOPE**	**3**
2	**INTRODUCTION**	**3**
2.1	Definition	3
2.2	Design Guidelines	3
3	**SIKA® CARBODUR® GRID C (CONCRETE) SYSTEM**	**4**
3.1	System Components	4
3.2	System Description	4
3.3	Technical Data	5
3.4	Mechanical and Design Values	6
4	**LEGAL NOTE**	**7**

1 SCOPE

This document describes the FRCM (***Fibre-Reinforced Cementitious Matrix/Mortar***) Systems available in the Sika® Product Range, it defines the System components, the suitable substrates and the design values to be used for the design calculations of strengthening.

2 INTRODUCTION

2.1 DEFINITION

FRCM Systems are created by using reinforcement grids made of aramid, basalt, carbon, PBO (Polybenzoxazoles) and glass fibre bundles/yarns, or by using unidirectional high-strength steel cords.

In international literature FRCM Systems are also referred to as TRC (Textile Reinforced Concrete), TRM (Textile Reinforced Mortars), FRM (Fabric Reinforced Mortar) or even IMG (Inorganic Matrix-Grid Composites).

Grids and strands are combined with inorganic matrices, made (for example) with lime or cement-based binders, with the possible addition of additives. In the case of organic additives, it is recommended that the organic component does not exceed 10% by weight of the inorganic binder.

FRCM composites are increasingly used in structural rehabilitation interventions instead of classic FRP (Fibre Reinforced Polymer) composites made with long glass, carbon or aramid fibres immersed in polymeric materials (such as epoxy resins). The inorganic matrix has some advantages over the organic FRP matrix, especially for applications to masonry structures, given its greater affinity for this type of substrate.

FRCM Strengthening Systems, in the case of a single-ply fabric application, have a thickness ranging between 5 and 15 mm, excluding the levelling of the substrate. In the case of multiple plies, the thickness increases, but it is not usually greater than 30 mm. The spacing between the yarns does not usually exceed two times the thickness of the mortar and in any case, it cannot be greater than 30 mm.

The high strength-to-weight ratio of FRCM Systems makes it possible to enhance the mechanical performance of the strengthened structural element, allowing it to withstand the tensile stresses without increasing its mass or significantly changing its stiffness.

In general, FRCM reinforcements demonstrate good chemical-physical compatibility with masonry and concrete substrates and a certain degree of vapour permeability; moreover, they can be prepared using familiar / traditional methods, even on wet surfaces. Due to their mechanical properties, FRCM reinforcements are specifically suitable for applications requiring limited deformations, as typically occurs with the strengthening of masonry.

2.2 DESIGN GUIDELINES

Some design guidelines are available in the international field for the qualification of FRCMs and for the design of structural strengthening of structures, carried out with such materials. The US acceptance criteria (ACI 434 - *Acceptance Criteria for Masonry and Concrete Strengthening Using Fiber-Reinforced Cementitious Matrix (FRCM) Composite Systems*, issued by ICC Evaluation Service, 2018) and the design guidelines (RILEM TC 250-CSM & ACI 549 - *Guide to Design and Construction of Externally Bonded Fabric-Reinforced Cementitious Matrix (FRCM) and Steel Reinforced Grout (SRG) Systems for Repair and Strengthening Masonry Structures*) can be referenced.

The only Eurocode based available and approved guideline is the Italian CRN-DT 215/2018 ("*Guide for the Design and Construction of Externally Bonded Fibre Reinforced Inorganic Matrix Systems for Strengthening Existing Structures*").

The purpose of this guideline is to provide, within the framework of the Italian regulations (and therefore of the Eurocode), a document for the design and construction of externally bonded FRP Systems for strengthening existing structures.

In the guideline is possible to find the equations to design FRCM reinforcement of masonry structures and reinforced concrete (RC) structures.

3 SIKA® CARBODUR® GRID C (CONCRETE) SYSTEM

This FRCM System is mainly intended for the strengthening of concrete structures.

It can be used for flexural or shear strengthening of reinforced concrete (RC) beams and for the confinement of RC columns.

It can also be used for the strengthening of buried structures, concrete pipes, cooling towers and in all the situations where it is difficult or not possible to apply a classic FRP System (for example on green concrete substrates, permanently humid or wet environments, and in high service temperatures).

3.1 SYSTEM COMPONENTS

Reinforcement Grid - Sika® CarboDur®-300 Grid

Matrix / Mortar - Sika® MonoTop®-3200 Grid

<u>Conventional Substrate - Concrete</u>

3.2 SYSTEM DESCRIPTION

<u>Grid:</u>

Product Name	***Fibre Orientation***	**Type of Fibre**	**Weight [g/m²]**
Sika® CarboDur®-300 Grid	*Bi-directional*	High strength bi-directional, non-woven balanced carbon fibre grid, impregnated with a special coating	Total: 340 Fibre: 226

<u>Mortar:</u>

Product Name	**Description**
Sika® MonoTop®-3200 Grid	Sika® MonoTop®-3200 Grid is a one-part, cementitious, low shrinkage, surfacing / finishing mortar. It is designed to be used in combination with the Sika® CarboDur®-300 Grid as part of the Sika® CarboDur® Grid C System which provides an efficient Strengthening System for concrete structures

3.3 TECHNICAL DATA

Characteristic	Values	U.O.M.	Test Method / Standard
Nominal Thickness of the System	4-8	[mm]	
Total Weight of the Grid	340 ± 10	[g/m²]	
Total Weight of Fibres in Weft Direction			
Carbon Fibres	104 ± 5	[g/m²]	
Glass Fibres	9 ± 2	[g/m²]	
Total Weight of Fibres in Warp Direction			
Carbon Fibres	104 ± 5	[g/m²]	
Glass Fibres	9 ± 2	[g/m²]	
Equivalent Thickness of the Grid in Weft Direction	0.057	[mm]	CNR-DT 215 (§ 2)
Equivalent Thickness of the Grid in Warp Direction	0.057	[mm]	CNR-DT 215 (§ 2)
Density of Carbon Fibre	1.80 ± 2	[g/cm³]	
Percentage of Organic Compounds in the Matrix	< 10	%	
Reaction to Fire of the Mortar	EuroClass A1		UNI EN 13501-1
CE Marking of the Mortar	Class R3		EN 1504-3

3.4 MECHANICAL AND DESIGN VALUES

Characteristic	Concrete Substrate	Units	Test Method / Standard
$\sigma_{lim,conv}$ (Conventional stress limit)	2730	[MPa]	CNR-DT 215 (§§ 2.1-7.2)
$\sigma_{lim,conv,ck}$ (Conventional stress limit, char.)	2270	[MPa]	CNR-DT 215 (§§ 2.1-7.2)
$\varepsilon_{lim,conv}$ (Conventional strain limit)	1.20	%	CNR-DT 215 (§§ 2.1-7.1)
$\varepsilon_{lim,conv,ck}$ (Conventional strain limit, char.)	1.00	%	CNR-DT 215 (§§ 2.1-7.1)
E_1 (Young's Modulus of elasticity of uncracked FRCM)	2 987 000	[MPa]	CNR-DT 215 (§§ 2.1-7.1.2)
σ_u (Ultimate tensile stress of FRCM, referred to fibres)	3680	[MPa]	CNR-DT 215 (§§ 2.1-7.1.2)
$\sigma_{u,ck}$ (Ultimate tensile stress of FRCM, characteristic)	3490	[MPa]	CNR-DT 215 (§§ 2.1-7.1.2)
ε_u (Ultimate tensile strain of FRCM)	1.70	%	CNR-DT 215 (§§ 2.1-7.1.2)
σ_{uf} (Ultimate tensile stress of dry fibres)	3480	[MPa]	CNR-DT 215 (§§ 2.1-7.1.1)
$\sigma_{uf,ck}$ (Ultimate tensile stress of dry fibres, char.)	3020	[MPa]	CNR-DT 215 (§§ 2.1-7.1.1)
E_f (Young's modulus of elasticity of dry fibre)	223 000	[MPa]	CNR-DT 215 (§§ 2.1-7.1.1)
ε_{uf} (Ultimate tensile strain of dry fibres)	1.55	%	CNR-DT 215 (§§ 2.1-7.1.1)
$f_{c,mat}$ (Compressive strength of the matrix)	~30	[MPa]	EN 12190

NOTE: *Characteristic values (with the subscript "$_{ck}$") represents the fractile 5% and they are obtained by subtracting two times the standard deviation from the mean value of the tests performed. All the values without the subscript "$_{ck}$" are mean values. All the data refer to weft direction. For any additional information, refer to the relevant Product Data Sheet*.

4 LEGAL NOTE

The information contained herein and any other advice are given in good faith based on Sika's current knowledge and experience of the products when properly stored, handled and applied under normal conditions in accordance with Sika's recommendations. The information only applies to the application(s) and product(s) expressly referred to herein and is based on laboratory tests which do not replace practical tests. In case of changes in the parameters of the application, such as changes in substrates etc., or in case of a different application, consult Sika's Technical Service prior to using Sika products. The information contained herein does not relieve the user of the products from testing them for the intended application and purpose. All orders are accepted subject to our current terms of sale and delivery. Users must always refer to the most recent issue of the local Product Data Sheet for the product concerned, copies of which will be supplied on request.

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