TECHNICAL JUSTIFICATION FOR THE APPLICATION OF GFRP REINFORCEMENT

in Concrete Structures

Properties · Design Considerations · Durability · Quality Control

Engineering Reference Document

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info@imaracomposites.com +255 790 555 555 imaracomposites.com

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PRODUCTS

- GFRP Rebar
- Bent Elements (including dowels & fixing elements)
- GFRP Mesh
- Structural Microfibres

Executive Engineering Summary

GFRP is a glass-fibre-reinforced polymer composite reinforcement for concrete structures, in which continuous glass fibres carry the primary tensile forces, while the polymer matrix binds and protects the fibres, forms the bar, and contributes to bond with the concrete.

GFRP is an independent engineering material and should not be treated as a direct “one-to-one” substitute for steel reinforcement. Design requires a separate check of strength, deflection, crack width, anchorage, shear, and service conditions.

Key Advantage	Design Consideration
No electrochemical corrosion	Lower modulus of elasticity compared to steel
High tensile strength	Linear-elastic behaviour with no yield plateau
Light weight	Mandatory deflection and crack-width control
Electromagnetic neutrality	Special anchorage requirements and bent-bar limitations
Low thermal and electrical conductivity	Restrictions under fire and seismic loading

The most technically justified applications are: marine and coastal infrastructure, drainage and road structures, tanks, precast concrete products, chemically aggressive facilities, and structures requiring electromagnetic neutrality.

1. Purpose of the Document

This document is intended for structural designers, design engineers, technical consultants, contractors, developers, client representatives, and construction-materials specialists.

It covers the properties of GFRP, its behaviour in concrete, differences from steel reinforcement, design principles, durability, limitations, recommended applications, and product quality-verification requirements.

2. Material and Construction of the GFRP Bar

GFRP consists of continuous glass fibres bound by a polymer matrix. Glass fibre provides the primary longitudinal tensile strength. The polymer matrix transfers forces between the fibres, protects them from the environment, and forms the geometry of the bar.

To achieve bond with concrete, the following surface treatments are used:

- sand coating;
- helical wrapping;
- helical wrapping with sand coating;
- ribbed / deformed profile;
- mechanically formed protrusions.

The surface form and the consistency of its execution directly affect bond with concrete and must be included in the quality-control programme.

3. Key Engineering Properties

- high tensile strength;
- low self-weight;
- resistance to electrochemical corrosion;
- non-magnetic and electromagnetically neutral;
- low electrical and thermal conductivity;
- high fatigue strength;
- ease of transport, cutting, and installation.

The high strength-to-weight ratio reduces loads during transport and loading, simplifies handling of reinforcement on site, and reduces the need for heavy lifting equipment.

4. Comparison with Reinforcing Steel

Characteristic	GFRP Reinforcement	Steel Reinforcement
Corrosion	Not subject to electrochemical corrosion	Possible under exposure to moisture, salts, and chlorides
Tensile behaviour	Linear-elastic up to failure	Elastic behaviour followed by yielding
Modulus of elasticity	Lower	Higher
Weight	Low	Significantly higher
Magnetic properties	Non-magnetic	Magnetic
Thermal / electrical conductivity	Low	High
On-site bending	Not permitted	Possible using appropriate technique
High temperature	Limited by the polymer matrix	Higher resistance

The main design difference stems from the lower modulus of elasticity and the absence of yielding. In many cases the final GFRP area is governed by serviceability limits rather than by tensile strength alone.

5. Behaviour Under Load

GFRP behaves predominantly in a linear-elastic manner up to failure. The material has no pronounced yield point and does not provide the same plastic redistribution of forces as steel.

Design must ensure:

- the required load-bearing capacity;
- deflection control;
- crack-width control;
- adequate anchorage;
- prevention of premature bar rupture;
- a failure mechanism intended by design.

For flexural members, a mechanism in which the ultimate limit state is reached through concrete crushing in the compression zone is preferable to sudden rupture of the GFRP.

6. Strength and Serviceability

Because of the lower modulus of elasticity, GFRP-reinforced members may exhibit larger deflections and wider cracks. The following must therefore be checked separately:

- load-bearing capacity;
- short-term and long-term deflection;
- crack width;
- bar spacing;
- bond with concrete and anchorage length;
- shear strength.

For the same reinforcement area, a GFRP-reinforced member typically deflects more than a comparable steel-reinforced member. This precludes automatic bar substitution based on matching diameter.

7. Design of Flexural Members

For beams and slabs, “diameter-for-diameter” or “bar-for-bar” substitution without a separate calculation is incorrect, owing to differences in modulus of elasticity, design strength, bond, deformation, and failure mode.

The design must determine:

- the design tensile strength of the GFRP;
- the effective section depth and neutral-axis position;
- concrete and reinforcement strains;
- the ultimate limit state of the concrete compression zone;
- the required GFRP area;

- crack width and deflection;
- anchorage length and bar spacing.

The contribution of GFRP to compression-zone resistance is generally disregarded; compressive resistance is taken as provided by the concrete.

8. Shear Design

The shear behaviour of GFRP-reinforced members differs owing to the lower modulus of elasticity, wider diagonal cracks, reduced aggregate interlock, lower dowel stiffness, and reduced bar strength at the bend.

The concrete contribution must be determined using a methodology developed for GFRP structures. When GFRP stirrups are used, the reduced strength of the bent portion must be taken into account. All bent elements are factory-made; on-site bending is not permitted.

9. Anchorage and Bond with Concrete

Bond is affected by surface type, diameter, concrete strength, cover, bar spacing, casting position, compaction quality, and transverse reinforcement.

The minimum anchorage length under the technical methodology considered is taken as not less than 305 mm or 20 bar diameters, whichever is greater, or the calculated length if it is greater still.

A mechanical connection must provide a strength of at least 1.25 times the guaranteed minimum ultimate tensile strength of the bar being connected.

10. Crack Control

Cracks do not cause corrosion of GFRP; however, their control is necessary for serviceability, watertightness, concrete durability, appearance, and limiting stiffness loss.

For some GFRP structures a crack width of up to approximately 0.7 mm may be permitted. This value is not applied automatically: the allowable width is established taking into account the purpose of the structure, watertightness requirements, climate, marine environment, freeze–thaw exposure, finishing, and client requirements.

11. Durability

Corrosion of steel can cause cracking and spalling of the cover, reduction of the reinforcement cross-section, loss of bond, and reduced load-bearing capacity. GFRP is not subject to electrochemical corrosion and is therefore particularly effective under exposure to seawater, marine air, chlorides, salts, moisture, and aggressive substances.

Field studies of structures 15–20 years old have shown good preservation of GFRP with no significant change in its properties. The durability of a specific product must be confirmed by testing for moisture absorption, alkaline resistance, strength retention, glass-transition temperature, degree of cure, and fibre content.

12. Temperature and Fire

The polymer matrix is sensitive to elevated temperatures. Heating can reduce mechanical properties and bond with concrete. Use in members with a mandatory fire-resistance rating therefore requires a separate calculation and technical substantiation, addressing:

- required fire-resistance rating;
- cover thickness;
- expected temperature within the member;
- glass-transition temperature of the matrix;
- duration of exposure;
- residual strength of the material;
- requirements of local codes.

13. Thermal Deformations

The coefficients of thermal expansion of GFRP differ along and across the fibres. Transverse expansion must be taken into account under sharp temperature changes, thin cover, small bar spacing, and the design of thermally loaded members.

14. Fabrication and Installation

- do not bend bars on site;
- do not allow surface damage or delamination;
- use suitable cutting methods;
- use appropriate chairs / spacers and tying materials;
- maintain cover, anchorage, and laps;
- do not substitute diameters without engineer approval;
- use only factory-bent elements;
- follow the manufacturer’s instructions for storage and installation.

Bars with delamination, deep cuts, damaged surface, or exposed fibres must not be installed without technical evaluation.

15. Material Quality Control

Design properties must be confirmed for each type and diameter. Values may vary between manufacturers, matrices, diameters, surfaces, and batches.

Parameter	Technical Reference Value
Glass-fibre content by mass	not less than 70%
Glass-transition temperature	not less than 100°C
Degree of cure	not less than 95%
Average tensile modulus of elasticity	not less than 44,800 MPa
Average ultimate strain	not less than 1.1%
Moisture absorption to saturation	not more than 1.0%
24-hour moisture absorption	not more than 0.25%
Strength retention after alkaline exposure	not less than 80% of initial
Strength of bent portion	not less than 60% of the straight-bar value
Transverse shear strength	not less than 131 MPa
Bond strength	not less than 7.6 MPa

The values above are technical reference points from the source material. Design properties must be adopted from confirmed data for the specific product and the requirements of the project.

16. Product Verification Documents

Recommended package from the manufacturer or supplier:

- technical data sheet and composition information;
- type of glass fibre and polymer matrix;
- nominal diameter and cross-sectional area;
- measured cross-sectional area;
- guaranteed tensile strength;
- modulus of elasticity and ultimate strain;
- bond strength and transverse strength;
- alkaline-resistance and moisture-absorption test results;
- glass-transition temperature, degree of cure, and fibre content;
- data on factory-bent elements;
- batch number and quality-control report;
- transport, storage, and installation instructions.

A laboratory report on individual samples confirms the properties of only the tested samples and does not automatically confirm all future commercial batches. Each batch must have identification and traceable control documentation.

17. Recommended Applications

17.1 Marine and Coastal Structures

- embankments, piers, and wharves;

- seawalls and retaining structures;
- coastal walkways and concrete platforms;
- drainage structures;
- port infrastructure.

17.2 Road Infrastructure

- bridge decks and precast panels;
- road slabs and concrete barriers;
- drainage channels, sidewalks, and parking areas.

17.3 Industrial and Aggressive Environments

- treatment plants and tanks;
- channels and process platforms;
- chemical facilities;
- concrete elements under sustained moisture exposure.

17.4 Electromagnetically Neutral Structures

- MRI equipment areas;
- laboratories and electrical substations;
- structures near sensitive measuring equipment.

17.5 Mining and Tunnel Construction

GFRP can be used in elements that are subsequently cut by tunnelling or mining equipment. Its light weight and ease of cutting facilitate temporary reinforcement and excavation.

17.6 Precast Concrete

- precast slabs, panels, beams, and walls;
- drainage elements;
- small foundations;
- stair elements and lintels;
- protective and infrastructure products.

18. Application Limitations

Separate engineering and code analysis is required for:

- seismic-resisting systems and elements carrying lateral loads;
- structures with a mandatory fire-resistance rating;
- prestressed structures;
- anchorage into existing concrete with adhesive systems;
- deep beams and complex joints;
- structures requiring high ductility;
- intense impact loading;

- elements with significant reinforcement compression;
- situations requiring on-site bending of reinforcement.

In seismic regions, GFRP should not be used as part of the primary lateral- and seismic-load-resisting system without special code-based and experimental justification.

19. Engineering Selection Procedure for GFRP

Stage	Scope of Verification
1. Service conditions	Determine exposure to seawater, chlorides, chemical environment, moisture, temperature, fire, and seismic action.
2. Structural function	Establish the role of GFRP: longitudinal, distribution, temperature-shrinkage, or shear reinforcement.
3. Material properties	Obtain guaranteed strength, modulus, strain, cross-sectional area, bond, and properties of bent elements.
4. Ultimate limit state	Check flexure, tension, compression zone, shear, punching, anchorage, and connections.
5. Serviceability	Check deflection, crack width, bar spacing, and long-term deformation.
6. Special effects	Consider temperature, fire, seismic action, fatigue, chemical environment, freezing, and impact.
7. Design specification	Specify type, diameters, confirmed properties, cover, anchorage, installation, and batch control.

20. Technical and Economic Feasibility

The use of GFRP is justified when the key requirements are corrosion resistance, long service life, low weight, non-magnetic behaviour, low conductivity, and operation in an aggressive environment.

The evaluation should not be limited to comparing the price of one metre of GFRP against steel. The life cycle should be considered: transport, installation, cover, corrosion risk, maintenance, repair, downtime, and design service life.

21. Conclusion

GFRP is a technically effective material for reinforcing concrete, provided the design accounts for its distinct mechanical behaviour. The material delivers the greatest value in marine, coastal, road, industrial, and municipal infrastructure, where steel corrosion limits durability.

Safe application requires calculation by a qualified engineer, confirmed properties of the specific product, production-batch control, compliance with design requirements, and applicable local building codes.

Basis of the Document

This document was prepared based on the following engineering reference standards:

- **ASTM D7957/D7957M-22** — ASTM International’s specification for solid round glass-fibre-reinforced polymer bars for concrete reinforcement. It establishes requirements for the material, geometric and mechanical properties, qualification testing, and quality control of GFRP bars.
- **ACI 440.11-22** — American Concrete Institute standard for the design of concrete structures reinforced with glass-fibre-reinforced polymer bars. It establishes design requirements for strength, serviceability, anchorage, crack control, and detailing of GFRP-reinforced members.

These documents are used as the engineering basis for describing material properties, product quality requirements, and design principles for concrete structures with GFRP reinforcement.

This material does not replace design documentation, the structural engineer’s calculations, manufacturer’s technical specifications, or the requirements of applicable building codes.

The best regards

IMARA COMPOSITES LTD

Website: imaracomposites.com
Email: info@imaracomposites.com
Tel: +255 790 555 555
Address: 368 Msasani Road, Kinondoni District, Dar es Salaam, United Republic of Tanzania

APPENDIX A

PRODUCT PORTFOLIO AND ARTICLE CODING

Product identification for engineering specifications, schedules and drawings

These annexes provide the principal product parameters, article structures and dimensional options available under the IMARA Composites product range. They are intended to support product selection, engineering specifications, schedules and construction drawings.

A.1 Product line structure

Family code	Commercial line	Product name
IMC-RB	IMARA BAR	IMARA Composites GFRP Rebar Without Sand Coating
IMC-MS	IMARA GRID	IMARA Composites GFRP Composite Mesh
IMC-BE	IMARA SHAPE	IMARA Composites GFRP Bent Elements
IMC-MF	IMARA FIBRE	IMARA Composites Polypropylene Macrofibre

A.2 Article structure

Level	Purpose	Example
Family code	Identifies the product line	IMC-RB
Base model	Identifies material-significant geometry	IMC-RB-OD080-CD070
Commercial SKU	Adds supply form, dimensions and package	IMC-RB-OD080-CD070-ST-L12000

A.3 Coding rules

- IMC is the controlled article prefix for IMARA Composites.
- Diameter codes are recorded in tenths of a millimetre: D040 = 4.0 mm; D055 = 5.5 mm.
- Product geometry, supply form and principal dimensions are encoded directly in the article number.
- The complete SKU should be stated in project specifications, reinforcement schedules, bills of quantities and purchase descriptions.

APPENDIX B

IMARA GFRP REBAR

Product technical annex - IMARA BAR / Family code IMC-RB

B.1 Product definition

Parameter	Declared technical data
Official product name	IMARA Composites GFRP Rebar Without Sand Coating
Material	Four-component epoxy-based compound with continuous glass roving
Surface	Deformed / periodic profile; no sand coating
Outer and core diameter tolerance	+/- 0.5 mm
Tensile strength, OD 4-13 mm	>= 1,000 MPa
Tensile strength, OD 14-30 mm	>= 800 MPa
Tensile modulus, OD 4-13 mm	>= 50,000 MPa
Tensile modulus, OD 14-30 mm	>= 45,000 MPa
Compressive strength	>= 300 MPa
Straight-bar length	Up to 12 linear metres
Coil option	50 linear metres for selected diameters up to OD 12 mm
Manufacturer specification	TU 2296-001-60722703-2010
Manufacturer test method	GOST 32492-2015, clauses 5 and 6
Engineering product reference	ASTM D7957/D7957M-22
Structural design reference	ACI 440.11-22

B.2 Supply and handling

- Straight bars of the same grade are packed in bundles of 5-50 pieces and secured with tape.
- Each coil is supplied as an individual unit. Product marking is applied by label.
- Bars must not be bent on site; use factory-manufactured bent elements where bends are required.
- Protect bars from impact, delamination, deep cuts and exposure of fibres during transport, storage and installation.

B.3 Qualification properties referenced in this document

Property	Technical reference value
Glass-fibre content by mass	>= 70%
Glass-transition temperature	>= 100 C
Degree of cure	>= 95%
Average ultimate strain	>= 1.1%
Moisture absorption to saturation	<= 1.0%
24-hour moisture absorption	<= 0.25%
Strength retention after alkaline exposure	>= 80% of initial
Transverse shear strength	>= 131 MPa
Bond strength	>= 7.6 MPa

APPENDIX B-2

IMARA GFRP REBAR SIZE MATRIX

Base product models and commercial SKU extension rules

Outer diameter, mm	Core diameter, mm	Base article
4.0	3.0	IMC-RB-OD040-CD030
5.0	4.0	IMC-RB-OD050-CD040
5.5	4.5	IMC-RB-OD055-CD045
6.0	5.0	IMC-RB-OD060-CD050
7.0	6.0	IMC-RB-OD070-CD060
8.0	7.0	IMC-RB-OD080-CD070
9.0	8.0	IMC-RB-OD090-CD080
10.0	9.0	IMC-RB-OD100-CD090
12.0	10.5	IMC-RB-OD120-CD105
14.0	12.5	IMC-RB-OD140-CD125
16.0	14.5	IMC-RB-OD160-CD145
18.0	16.5	IMC-RB-OD180-CD165
20.0	18.5	IMC-RB-OD200-CD185
22.0	20.5	IMC-RB-OD220-CD205
24.0	23.5	IMC-RB-OD240-CD235
26.0	24.5	IMC-RB-OD260-CD245
28.0	26.5	IMC-RB-OD280-CD265
30.0	28.5	IMC-RB-OD300-CD285

Commercial SKU extensions

Code	Meaning	Example
ST	Straight bar	IMC-RB-OD080-CD070-ST-L12000
CL	Coil	IMC-RB-OD080-CD070-CL-L50000
Lxxxxx	Supplied length in millimetres	L12000 = 12 m; L50000 = 50 m

APPENDIX C

IMARA GFRP COMPOSITE MESH

Product technical annex - IMARA GRID / Family code IMC-MS

Parameter	Declared technical data
Official product name	IMARA Composites GFRP Composite Mesh
Bar outer diameters	2.0 / 2.5 / 3.0 / 4.0 / 5.0 / 6.0 mm
Mesh opening / spacing	50 x 50 / 100 x 100 / 150 x 150 / 200 x 200 mm
Sheet dimensions	Width 1 or 2 m; length from 1 to 12 m
Roll dimensions	Roll length up to 25 m; approved width to be stated in the order
Material	Four-component epoxy-based compound with glass roving
Tensile strength of working transverse bar	>= 800 MPa
Tensile modulus of working transverse bar	>= 50,000 MPa
Joint construction	Longitudinal and transverse bars are interwoven and bonded with epoxy resin
Manufacturer specification	TU 23.14.12-002-00227637-2023
Permitted unbonded intersections	No more than two intersections per 1 m2 of mesh
Permitted resin beads	Up to 1.0 mm high at 100 mm spacing
Supply form	Sheets or rolls; each unit identified by label

C.1 Article structure

IMC-MS-D[bar diameter]-S[mesh spacing]-[format]-W[width]-L[length]

Code group	Available code values
Bar diameter	D020 / D025 / D030 / D040 / D050 / D060
Mesh spacing	S050 / S100 / S150 / S200
Format	SH = sheet; RL = roll
Dimensions	W and L are stated in millimetres

Examples

- IMC-MS-D040-S100-SH-W2000-L6000: 4 mm bar, 100 x 100 mm spacing, 2 x 6 m sheet.
- IMC-MS-D030-S050-RL-W1000-L25000: 3 mm bar, 50 x 50 mm spacing, 1 x 25 m roll.

APPENDIX D

IMARA GFRP BENT ELEMENTS

Product technical annex - IMARA SHAPE / Family code IMC-BE

Parameter	Declared technical data
Official product name	IMARA Composites GFRP Bent Elements
Shapes	L-shaped, U-shaped, square and custom elements to an approved drawing
Outer diameter range	3-12 mm
Surface	Deformed / periodic or nominally smooth profile
Maximum size	Not more than 1 metre on each side of the element
Material	Four-component epoxy-based compound with glass roving
Manufacturing method	Factory-made only; on-site bending is not permitted
Strength of bent portion	>= 60% of the straight-bar strength
Product definition	Manufactured to an approved project or product drawing
Dimensions and tolerances	Specified in the applicable drawing or product schedule

D.1 Article structure

IMC-BE-[shape]-D[diameter]-[profile]-DRW[drawing]-R[revision]

Code	Meaning
L	L-shaped element
U	U-shaped element
SQ	Square element / stirrup
CU	Custom configuration
PR	Deformed / periodic profile
SM	Nominally smooth profile

Examples

- IMC-BE-L-D080-PR-DRW001-R01
- IMC-BE-U-D100-PR-DRW002-R01
- IMC-BE-SQ-D060-SM-DRW003-R01

D.2 Geometry data for specification

- All leg dimensions, bend radius, bar outer diameter and surface profile.
- Dimensional tolerances and orientation of the element in the structure.
- Required straight and bent-portion mechanical properties.
- Drawing or schedule reference used for product identification.

APPENDIX E

IMARA POLYPROPYLENE MACROFIBRE

Product technical annex - IMARA FIBRE / Family code IMC-MF

Parameter	Declared technical data
Official product name	IMARA Composites Polypropylene Macrofibre
Material	100% pure virgin polypropylene
Fibre length	30-40 mm
Equivalent diameter	0.7-1.0 mm
Tensile strength	>= 80 MPa
Recommended dosage	In accordance with project documentation
Manufacturer specification	TU 20.60.13-001-24067351-2022
Polymer-fibre reference	EN 14889-2
Fibre-reinforced concrete reference	ASTM C1116/C1116M
Packaging	Labelled packages from 1 to 5 kg

E.1 Article structure

IMC-MF-PP-L3040-E0710-P[package mass in grams]

Article	Description
IMC-MF-PP-L3040-E0710-P1000	Polypropylene macrofibre, 30-40 mm, equivalent diameter 0.7-1.0 mm, 1 kg package
IMC-MF-PP-L3040-E0710-P5000	Polypropylene macrofibre, 30-40 mm, equivalent diameter 0.7-1.0 mm, 5 kg package

APPENDIX E - CONTINUED

COMPARATIVE CONCRETE PERFORMANCE

Reference laboratory test data for B22.5 concrete with polypropylene macrofibre

E.2 Test basis

The data below reproduce the engineering-relevant results stated in OOO "Polovik" Test Report No. 15 dated 25 March 2025. The report compares B22.5 concrete without fibre with concrete containing 3 kg/m^3 of ArmFiber polypropylene fibre identified to TU 20.60.13-001-24067351-2022, the manufacturer specification referenced for this product family.

Parameter	Test configuration stated in the report
Concrete class	B22.5
Reference composition	Control concrete without fibre
Fibre composition	Polypropylene fibre dosage: 3 kg/m^3
Compression specimens	Cubes, 100 x 100 x 100 mm; two recorded results at each test age
Compression test ages	3, 7 and 28 days
Flexural test	Beam specimens tested at 28 days
Ambient conditions	20 °C; relative humidity 55%
Recorded cube mass range	Control: 2300-2365 g; fibre mix: 2325-2385 g
Project strength stated for B22.5	28.8 MPa

E.3 Compressive-strength results

Age, days	Control results, MPa	Control mean*, MPa	Fibre results, MPa	Fibre mean*, MPa	Change in mean*
3	20.1; 21.4	20.75	21.3; 21.4	21.35	+2.9%
7	24.3; 24.3	24.30	26.1; 26.1	26.10	+7.4%
28	33.0; 31.7	32.35	35.0; 35.2	35.10	+8.5%

E.4 Flexural-strength result

Characteristic	Control concrete	Fibre concrete, 3 kg/m^3	Relative change*
Flexural strength at 28 days	10.6 MPa	15.7 MPa	+48.1%

* Arithmetic means and percentage changes are calculated from the individual values printed in the report. They are provided for comparison only and are not statistical characteristic values or design strengths. The results apply only to the tested concrete composition, fibre dosage, specimen geometry, curing and test conditions. Project use requires verification against the applicable structural design requirements and the approved concrete mix design.