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भारतीय मानक

Indian Standard

IS 18256 : 2023

कंक्रीट प्रबलन के लिए काँच रेशा प्रबलित पॉलिमर (जीएफआरपी) के ठोस गोल सरिए — विशिष्टि

Solid Round Glass Fibre Reinforced Polymer (GFRP) Bars for Concrete Reinforcement — Specification

ICS 83.120; 91.100.30

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Concrete Reinforcement Sectional Committee, CED 54

FOREWORD

This Indian Standard was adopted by the Bureau of Indian Standards, after the draft finalized by the Concrete Reinforcement Sectional Committee had been approved by the Civil Engineering Division Council.

This standard has been formulated to cover requirements for glass fibre reinforced polymer (GFRP) bars for concrete reinforcement. GFRP bars are used across the world as an alternative to steel bars in reinforced concrete. Recently, India is also witnessing the manufacturing and use of such bars. However, their use in concrete has to be judiciously decided based on the design specifications associated with various physical, chemical and mechanical properties. This standard contains only specifications for type of fibres, resin and required minimum physical, chemical and mechanical properties of GFRP bars. It describes the permitted constituent materials, limits on constituent volumes, and minimum performance requirements for GFRP bars to be used as reinforcement for non-prestressed concrete. Guidance on deciding a suitable resin and fibre material shall be evaluated based on this standard. Standards on test methods and design provisions of using GFRP bars should complement this standard.

The GFRP bars in accordance with this standard may be used for applications in reinforced concrete elements with low-risk (that is, where consequences of failure are less, as judged by the engineer in-charge). Examples of such elements include slab-on-grade (say, pavements and floorings), drainage structures, fences, and manhole covers. For suitable application of these reinforcing bars in roads, highways and bridges, relevant guidelines/standards of Indian Roads Congress may be referred to.

The Engineer in-Charge shall certify or obtain certification stating that the specific concrete elements reinforced with GFRP bars can meet the target criteria on serviceability, strength, and durability for the design life of such elements.

Assistance has been derived from the following standards and publications in the preparation of this standard:

a) ASTM D7957/D7957M-22 Standard specification for solid round glass fiber reinforced polymer bars for concrete reinforcement;
b) ACI SPEC-440.6-08(17)(22) Specification for carbon and glass fiber-reinforced polymer bar materials for concrete reinforcement;
c) ACI CODE-440.11-22 – Building code requirements for structural concrete reinforced with glass fiber reinforced polymer (GFRP) bars — Code and commentary; and
d) 'Design Manual No. 3 Reinforcing concrete structures with fiber reinforced polymers' by ISIS Canada Research Network (September 2007).

This standard contributes to the United Nations Sustainable Development Goal 9 — Industry, innovation and infrastructure: Build resilient infrastructure, promote inclusive and sustainable industrialization and foster innovation.

The composition of the Committee and the Working Group responsible for formulation of this standard is given in Annex D.

For the purpose of deciding whether a particular requirement of this standard is complied with, the final value, observed or calculated, in reporting the result of a test or analysis, shall be rounded off in accordance with IS 2 : 2022 'Rules for rounding off numerical values (*second revision*)'. The number of significant places retained in the rounded off value should be the same as that of the specified value in this standard.

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Indian Standard

SOLID ROUND GLASS FIBRE REINFORCED POLYMER (GFRP) BARS FOR CONCRETE REINFORCEMENT — SPECIFICATION

1 SCOPE

1.1 This standard covers the requirements for solid round glass fibre reinforced polymer (GFRP) straight bars, provided in cut lengths or coils, and bent bars or stirrups; and having an external surface enhancement for use as concrete reinforcement.

1.2 The following GFRP materials are not covered by this standard:

a) Bars made of more than one load-bearing fibre types (that is, hybrid FRP);
b) Bars having no external surface enhancement (that is, plain or smooth bars, or dowels);
c) Bars with geometries other than solid, round cross-sections;
d) Bars with even traces of polyester in the base polymer/resin; and
e) Couplers and bars connected with couplers.

1.3 IS 18255 is a necessary adjunct to this standard.

2 REFERENCES

The standards listed below contain provisions, which through reference in this text constitute provisions of this standard. At the time of publication, the editions indicated were valid. All standards are subject to revision, and parties to agreements based on this standard are encouraged to investigate the possibility of applying the most recent editions of the standards listed below:

IS No.	*Title*
IS 18255 : 2023	Fibre-reinforced polymer (FRP) bars for concrete reinforcement — Methods of test

3 TERMINOLOGY

For the purpose of this standard, the following definitions shall apply.

3.1 Bar — A straight or bent element with a solid, round cross section in the straight portion, having surface enhancement that intends to provide mechanical interlock with concrete.

3.2 Batch — Any quantity of bar produced from start to finish with the same constituent materials used in the same proportions without changing any production parameter, such as cure temperature and line speed.

3.3 Bundle — Two or more coils or a number of lengths properly bound together.

3.4 Bend Angle — The intentional deviation of a portion of a bar from the main axis of the bar, measured in degrees.

3.5 Bend Radius — The inside radius of a bent bar, as provided in Table 1.

3.6 Guaranteed Property — A characteristic value provided by the manufacturer less than or equal to the mean minus three standard deviations of the samples tested according to a specified method.

3.7 Mean Property — A value provided by the manufacturer less than or equal to the mean of the samples tested according to a specified method.

3.8 Measured Cross-Sectional Area — The average cross-sectional area of a representative bar, including deformations, lugs, sand coating or any bond-enhancing surface treatment, measured according to IS 18255.

3.9 Nominal Diameter — The standard diameter of a bar, as described in Table 1.

3.10 Nominal Cross-Sectional Area — The standard cross-sectional area of a bar, as described in Table 1.

3.11 Lot — Any quantity of bars of same size and same minimum guaranteed ultimate tensile force in bundles, presented for examination and tests at a time.

3.12 Size Designation — An alphanumeric identifier corresponding to bar designation number of Table 1.

3.13 Surface Enhancement — Protrusions, lugs, sand coatings, deformations or any additional

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surface treatment that provides means of mechanically transmitting force between the bar and the concrete surrounding the bar in such construction.

3.14 Test, Certification — An optional test, specified by the purchaser, to certify that the material provided for a given project meets the requirements of the standard.

3.15 Test, Qualification — A test completed under the supervision of the manufacturer to ensure conformance of the material to the requirements of a standard.

3.16 Test, Quality Control — A test completed on each production lot of material, under the supervision of the manufacturer, to ensure that the process of manufacturing the product remains under control.

4 ORDERING INFORMATION, CONSTITUENT MATERIALS AND MANUFACTURE

4.1 General Requirements

The following shall be considered while using GFRP bars:

a) Applications;
b) Mechanical loading conditions;
c) Environmental/chemical exposure conditions; and
d) Desired service life of the structural element.

4.2 Ordering Information

The purchase order shall include the following information:

a) Name of the GFRP material (manufacturer's description);
b) Type of surface enhancement;
c) Quantity of each individual bar length;
d) Bar size;
e) Cut length; and
f) For bent bars in circular/rectangular/spiral shapes, the shape of the bend, the diameter of the bend, the length of the legs and the angle, the radius of bending, as applicable.

The purchase order shall seek for the Manufacturers' Test Certificate (MTC), as per the MTC template given in Annex A.

4.3 Materials

4.3.1 *Fibres*

4.3.1.1 Fibres shall be in the form of unidirectional rovings (glass fibres) of given size and mass. Fibre sizing and coupling agents shall be compatible with the resin system used to impregnate.

4.3.1.2 The following types of glass are permitted to be used in GFRP bars:

a) *E-CR glass* — Chemically resistant conventional glass; and
b) *R glass* — High strength glass.

A comparison of the chemical compositions and physical properties of the above glass fibres used for manufacturing GFRP bars is given in Annex B for information.

4.3.2 *Matrix Resins*

4.3.2.1 Matrix resin shall comply with the following requirements:

a) Vinylester and epoxy resin systems are permitted provided the finished product meets the physical and durability requirements as specified in this standard.

b) Base polymer in the resin system shall not contain any polyester.

c) Styrene is permitted to be added to the vinylester resin during the processing/manufacturing of GFRP bar, provided the finished GFRP bar meets the physical and durability requirements as specified in this standard. Added styrene shall be less than 10 percent by mass of the polymer resin. The amount of styrene, as a mass percentage of the polymer resin, added during processing shall be reported.

4.3.3 *Fillers and Additives*

4.3.3.1 Only commercial-grade inorganic fillers such as kaolin clay, calcium carbonate, and alumina trihydrate are permitted, and shall not exceed 5 percent by mass of the polymer resin.

4.3.3.2 Only commercial-grade additives, such as release agents, low profile shrink additives, initiators, promoters, accelerators, catalysts, pigments, fire retardants, and ultraviolet inhibitors are permitted and their use depends on the processing/manufacturing method. Shrink additives, if used, shall be less than 10 percent by mass of the polymer resin.

4.3.3.3 The GFRP bars shall not have total filler plus additive content of more than 15 percent by mass of the polymer resin.

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4.4 Manufacturing Process and Safety

The manufacturer shall produce GFRP bars using variations of the pultrusion process. Process or material modifications are not permitted during the production of a single lot. The manufacturer shall document the general process used and report the date of production and production lot size in the Manufacturer's Test Certificate (MTC), as per the template given in Annex A.

The manufacturing facility and the manufacturing processes shall be such to ensure necessary air quality and include safety practices. Suitable work practices shall be followed to avoid harmful exposure to air-borne particulate matter generated during the manufacturing (say, cutting, fuzz) of GFRP bars. Personal protective equipment shall be provided to workers to prevent their exposure to fibres. Pictorial warning sign/precautionary notices shall be provided at suitable places of manufacturing to caution the workers that handling of fibres without PPEs may cause serious damage to health. Adequate equipment for extracting air-borne particles shall be installed.

5 PHYSICAL AND GEOMETRICAL PROPERTIES

5.1 Fibre Content

When determined in accordance with IS 18255, the fibre content (mass fraction) of the GFRP bar shall not be less than 75 percent. The fibres in the bars should be as straight as possible.

5.2 Glass Transition Temperature

The glass transition temperature, T_g, shall be measured on a suitable piece cut from the as-produced bar using the differential scanning calorimetry (DSC) method, as given in IS 18255. The glass transition temperature of the cured resin so determined shall not be less than 100 °C (*see* Note).

NOTE — This temperature does not represent the maximum permitted service temperature and is intended for purchaser's quality assurance only. This standard does not currently designate maximum service temperatures of GFRP bars. Individual manufacturers should be consulted to determine the appropriate maximum service temperature for each product.

5.3 Degree of Cure

The degree of cure when determined using test specimens cut from the as-produced bar in accordance with the method given in IS 18255 shall not be less than 95 percent.

5.4 Bar Sizes and Surface Enhancements

5.4.1 The following surface patterns on the GFRP bars shall be permitted:

a) Sand coated surface;
b) Braided surface;
c) Spiral wound ribbed surface;
d) Indented surface; and
e) Machined/milled surface.

5.4.2 The nominal diameter, nominal cross-sectional area, the minimum and maximum measured cross-sectional area, and minimum guaranteed ultimate tensile force of GFRP bars shall be as given in Table 1.

5.4.3 The measured (calculated) diameter of a GFRP bar is equivalent to that of a smooth round bar having the same area as the GFRP bar measured in accordance with IS 18255.

5.4.4 The nominal diameter of a GFRP bar to be used for designation and design shall be equal to the calculated diameter. When the calculated diameter does not correspond to one of the nominal values given in Table 1, the next immediately smaller nominal diameter given in Table 1 shall be used.

5.4.5 For the bars with spiral wound ribbed surface, the pitch (centre-to-centre) and cross-sectional dimensions of the spiral ribs shall be such that the required bar-concrete bond strength is achieved for specific applications.

5.5 Tolerance on Nominal Mass and Dimension

The measured cross-sectional area of the bar shall be determined in accordance with IS 18255 and shall be measured on the as-manufactured bar, including surface enhancements. The measured cross-sectional area shall be within the minimum and maximum area limits provided in Table 1.

6 MECHANICAL PROPERTIES

6.1 Ultimate Tensile Force

When determined in accordance with IS 18255, the ultimate tensile force shall meet the requirement given in Table 2 or Table 3 as applicable (*see* **9**).

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Table 1 Geometrical and Tensile Properties of GFRP Round Bars

(*Clauses* 3.5, 3.9, 3.10, 3.12, 5.4.2, 5.4.4, 5.5, 6.1, 8.2.1 *and* 8.2.2)

Sl No.	Bar Size Designation	Nominal Diameter	Nominal Cross-Sectional Area	Measured Cross-Sectional Area		Straight Bars Minimum Guaranteed Ultimate Tensile Force	Bent Bars	
				Min	*Max*		Minimum Guaranteed Ultimate Tensile Force for Straight Portion	Minimum Bend Radius
		mm	mm^2	mm^2	mm^2	kN	kN	mm
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
i)	G4	4	12.6	13	15 [18][1)]	11	6	12
ii)	G6	6	28.3	29	34 [40][1)]	23	14	18
iii)	G8	8	50.3	51	60 [70][1)]	40	24	24
iv)	G10	10	78.5	79	94	60	35	30
v)	G12	12	113.1	115	136	80	50	36
vi)	G16	16	201.1	207	241	130	80	48
vii)	G20	20	314.2	316	377	190	120	60
viii)	G25	25	490.9	493	589	270	160	100
ix)	G32	32	804.2	806	965	420	-	-

[1)] Values indicated in [ ] are applicable for sand coated bars only.

NOTES

1 The nominal cross-sectional area is calculated using the nominal diameter.
2 Minimum measured cross-sectional area is specified greater than the nominal cross-sectional area, considering the surface characteristics and consequential changes in the cross-sectional area. Also, the size effect is considered while determining the minimum guaranteed ultimate tensile load.
3 The bend radius is calculated as three times the bar diameter for the sizes up to G20, four times the bar dimeter for the sizes G25 and G32.

6.2 Tensile Modulus of Elasticity

When determined in accordance IS 18255, the tensile modulus of elasticity shall meet the requirement given in Table 2 or Table 3 as applicable (*see* **9**).

6.3 Ultimate Tensile Strain

The ultimate tensile strain shall be calculated by dividing the ultimate tensile force by the product of the nominal cross-sectional area and tensile modulus of elasticity. The ultimate tensile strain so calculated shall meet the requirement given in Table 2 or Table 3 as applicable (*see* **9**).

6.4 Transverse Shear Strength

When determined in accordance with IS 18255, the transverse shear strength shall meet the requirement given in Table 2.

6.5 Bond Strength

When determined in accordance with IS 18255 the bond strength shall meet the requirement given in Table 2.

6.6 Fatigue Tensile Strength

The residual tensile strength of bars, when tested after fatigue loading at a stress range of 15 percent to 45 percent of the ultimate tensile strength for 2 million cycles, shall meet the requirement given in Table 2. The ultimate tensile strength shall be calculated by dividing ultimate tensile force by measured cross-sectional area.

6.7 Creep Failure

When determined in accordance with IS 18255, the GFRP bar shall meet the requirement given in Table 2.

7 DURABILITY PROPERTIES

7.1 Moisture Absorption

When determined in accordance with IS 18255, the short term (24 h immersion) moisture absorption

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shall meet the requirement given in Table 2 or Table 3 as applicable (*see* **9**) and the long term moisture absorption shall meet the requirement given in Table 2.

7.2 Resistance to Alkaline Environment

The residual ultimate tensile force after exposure to the alkaline environment when determined in accordance with IS 18255 shall meet the requirement given in Table 2.

7.3 Longitudinal Wicking

Longitudinal wicking when determined in accordance with IS 18255 shall meet the requirement given in Table 2.

8 REQUIREMENTS FOR BENT BARS

8.1 Bending of bars should be prohibited at site.

8.2 Properties of Bends

8.2.1 Geometric properties for bent bars shall be as given in Table 1.

8.2.2 Ultimate tensile force of 90° bent bar shall meet the requirement given in Table 1.

8.2.3 When it is possible to extract a sufficiently long straight piece from a bent bar, the ultimate tensile force and tensile modulus of elasticity of the extracted straight portion shall be determined as per **11** of IS 18255 and shall meet the requirements given in Table 2 and Table 3, as applicable (*see* **9**).

8.2.4 When it is not possible to extract a sufficiently long straight piece from a bent bar, the ultimate tensile force of the 90° bent bar shall be determined in accordance with **20** of IS 18255 and shall meet the requirements given in Table 2 and Table 3, as applicable (*see* **9**).

9 SAMPLING AND FREQUENCY OF TESTING

9.1 Product Qualification

9.1.1 For the determination of the mean and guaranteed properties as given in Table 2, at least 24 samples shall be obtained in groups of eight or more, from three or more different production lots. For creep and fatigue tests, the number of samples shall be as decided by the purchaser and the manufacturer. Samples to be used for preparing test specimens shall be selected by the manufacturer on random basis. The mean and guaranteed properties shall satisfy the limits as given in Table 2.

Table 2 Property Limits for Product Qualification

(*Clauses* 6.2, 6.3, 6.4, 6.5, 6.6, 6.7, 7.1, 7.2, 8.2.3, 8.2.4, 9.1.1 *and* 9.1.3)

Sl No.	Property	Requirement
(1)	(2)	(3)
i)	Guaranteed glass fibre content (mass fraction)[1)]	≥ 75 percent
ii)	Mean glass transition temperature (T_g) or midpoint temperature	≥ 100 ºC
iii)	Mean degree of cure	≥ 95 percent
iv)	Mean measured cross-sectional area	As per Table 1
v)	Guaranteed ultimate tensile force[1)]	As per Table 1
vi)	Mean tensile modulus of elasticity	≥ 45 GPa
vii)	Mean ultimate tensile strain	≥ 1.1 percent
viii)	Guaranteed transverse shear strength[1)]	≥ 130 MPa
ix)	Guaranteed bond strength[1)]	≥ 7.6 MPa
x)	Mean residual fatigue tensile strength[2)]	≥ 60 percent
xi)	Creep failure criteria at a sustained service stress level of 35 percent of ultimate tensile strength[2)]	No rupture
xii)	Mean moisture absorption (short term)	≤ 0.25 percent
xiii)	Mean moisture absorption (long-term)	≤ 1 percent
xiv)	Guaranteed residual tensile force after 90 days of immersion in alkaline solution at 60 ºC[1)]	≥ 80 percent of mean ultimate tensile force of pristine bars
xv)	Guaranteed ultimate tensile force of 90º bent bar[1)]	≥ 60 percent of guaranteed tensile force of straight bar
xvi)	Longitudinal wicking	No continuous voids

[1)] Coefficient of variation of the properties tested should not be more than 0.1.

[2)] These tests are mandatory only for creep and fatigue sensitive applications.

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Table 3 Property Limits for Quality Control and Certification[1)]

(*Clauses* 6.1,6.2, 6.3, 8.2.3, 8.2.4, 9.2.1, 9.2.2 *and* 9.2.3)

Sl No.	Property	Requirement
(1)	(2)	(3)
i)	Glass fibre content (mass fraction)	≥ 75 percent
ii)	Glass transition temperature (T_g) or Midpoint temperature	≥ 100 ºC
iii)	Degree of cure	≥ 95 percent
iv)	Measured cross-sectional area	As per Table 1
v)	Ultimate tensile force	As per Table 1
vi)	Tensile modulus of elasticity	≥ 45 GPa
vii)	Ultimate tensile strain	≥ 1.1 percent
viii)	Moisture absorption (short term)	≤ 0.25 percent

[1)] For bent bars, the tests are performed on the straight portion of the bars.

9.1.2 Product qualification tests shall be repeated whenever a change is made in the chemical composition of the individual constituents or composite bar or the method of manufacture, or when a new size is to be introduced. Even if there are no such changes, these tests shall be done at least once every three years for all the bar sizes manufactured during the period.

9.1.3 If the purchaser intends to perform additional or independent product qualification testing, the need for additional test specimens shall be provided to the manufacturer. The manufacturer shall furnish requisite number of samples for carrying out these tests in accordance with IS 18255. The mean and guaranteed properties shall satisfy the limits as given in Table 2.

9.2 Quality Control and Certification

9.2.1 Quality control and certification tests as specified in Table 3 are carried out to assess the properties of a suitable sample size of bars for the purpose of acceptance of production lots at manufacturing units or consignment lot at construction sites.

9.2.2 For the determination of each of the property, random samples shall be obtained from each production lot or consignment. Samples of sufficient length shall be cut from each size of the finished bar at random at a frequency not less than that specified in Table 4. Number of specimens in one sample shall be as per IS 18255. Each individual sample shall satisfy the property limits as given in Table 3.

9.2.3 If an individual test result is not within the limits given in Table 3, that production lot/consignment shall be rejected as not meeting this standard.

10 MANUFACTURER'S TEST CERTIFICATE

The purchaser shall be furnished Manufacturer's Test Certificate (MTC) in the template as given in Annex A stating that the samples representing each lot have been tested as indicated in this standard and the requirements have been met. The MTC shall include the production lot number, traceable through the identifying markings on the bundles/coils of bars.

11 TRANSPORTATION, HANDLING, AND STORAGE

11.1 GFRP bars of diameter 12 mm or less shall be either transported in coils or straight lengths. Bars of diameter more than 12 mm shall be transported in bundles of 8 m or 12 m length within a tolerance of $^{+75}_{-25}$ mm. While transporting and storing the bar bundles, care shall be taken such that the bar bundles are well-separated and protected from abrasion and sunlight. The general handling and storage guidelines for GFRP bars shall be as given in Annex C.

Table 4 Frequency of Sampling for Quality Control and Certification

(*Clause* 9.2.2)

Sl No.	Bar Size	For Lot Sizes up to 25 Tonnes	For Lot Sizes above 25 Tonnes
(1)	(2)	(3)	(4)
i)	< 10 mm	One sample every 8 tonnes	One sample every 10 tonnes
ii)	10 to 16 mm	One sample every 10 tonnes	One sample every 12 tonnes
iii)	> 16 mm	One sample every 12 tonnes	One sample every 15 tonnes

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11.2 The maximum total unrepaired visible damage permitted on each linear metre of each GFRP bar shall not exceed 2 percent of the surface area in that linear metre of bar. The depth of the permissible damage shall not exceed 0.1 mm.

12 IDENTIFICATION AND MARKING

12.1 The manufacturer or supplier shall have bundles/coils of bars marked in such a way that all finished bars can be traced to the batch from which they were made.

12.1.1 *Marking on Bars*

All bars should be identifiable by marks/ brands introduced during manufacturing. Indelible and legible identification marks that include name of the manufacturer or their brand name, registered trade-mark, bar size designation and minimum guaranteed ultimate tensile force of bar shall be provided on each bar at an interval of every two metres.

12.1.2 *Identification of Bundles/Coils*

For each bundle/coil of GFRP bars, a tag shall be attached indicating name of the manufacturer or their brand name, registered trade-mark, bar size designation, minimum guaranteed ultimate tensile force of bar, production lot number and month and year of manufacturing.

12.1.3 *BIS Certification Marking*

GFRP bars conforming to the requirements of this standard may be certified as per the conformity assessment schemes under the provisions of the *Bureau of Indian Standards Act*, 2016 and the Rules and Regulations framed thereunder, and the bars may be marked with the Standard Mark.

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ANNEX A

(*Clauses* 4.2, 4.4 *and* 10)

TEMPLATE FOR MANUFACTURER'S TEST CERTIFICATE (MTC) FOR SOLID ROUND GLASS FIBRE REINFORCED POLYMER (GFRP) BARS FOR CONCRETE REINFORCEMENT

MANUFACTURER'S TEST CERTIFICATE (MTC) FOR SOLID ROUND GLASS FIBRE REINFORCED POLYMER (GFRP) BARS FOR CONCRETE REINFORCEMENT

NAME, LOGO AND ADDRESS OF THE MANUFACTURER:

Test Certificate Number		Delivery Assignment (DA) Number	
Test Certificate Date		DA Date	
Wagon/Truck Number		Total DA Weight	
Manufacturing Location		DA Type	
Approved by Production: Date: (Name and signature)		Approved by Quality: Date: (Name and signature)	
Approved by Other: Date: (Name and signature)			
Consignee Name and Address:			

It is certified that material described in Part A and delivered as per the above details, fully conforms to chemical, physical, mechanical, and durability properties of the GFRP bars, as stipulated in IS 18256. Samples representing each production lot have been tested and inspected as indicated in the Indian Standard and the results of the various tests conducted as per IS 18255 are provided in Part B of this MTC.

Tests performed by: (Name, designation, signature, date)	Authorised signatory: (Name, designation, signature, date)

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MANUFACTURER'S TEST CERTIFICATE (MTC) FOR SOLID ROUND GLASS FIBRE REINFORCED POLYMER (GFRP) BARS FOR CONCRETE REINFORCEMENT (*Continued*)

PART A — GENERAL

Product Details

Bar size designation		For bent bars,	
Cut length		a) Shape of the bend	Circular/Rectangular/Spiral
Type of surface enhancement		b) Diameter of the bend	
Batch Number including date of manufacturing		c) Radius of the bend	
Whether tested for creep and fatigue properties ?	Yes/No	d) Length of the legs and the angle of the bend	

Details of Constituent Materials

Type of fibre		Type of resin system	
Size of fibre		Whether styrene is added in resin (applicable only in case of vinylester resin)	Yes/No
Type of fillers		If yes, percentage of styrene by mass of the polymer resin:	
Percentage of fillers by mass of polymer resin			
Type of additives		Percentage of additives	
Percentage of shrink additives, if any, by mass of polymer resin		Percentage of total filler plus additive content by mass of polymer resin	
Any other information:			

Declared Chemical Composition of Fibres:

Product Name and Details	**Chemical Composition, in Percent**									
	SiO_2	Al_2O_3	CaO	MgO	B_2O_3	K_2O	Na_2O	ZrO_2	TiO_2	Others

Declared Physical Properties of Fibres:

Product Name and Details	**Physical Properties**					
	Density (g/cm^3)	Tensile strength (MPa)	Modulus of elasticity (GPa)	Ultimate strain (percent)	Coefficient of thermal expansion ($\times 10^{-6}$/°C)	Softening temperature (°C)

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MANUFACTURER'S TEST CERTIFICATE (MTC) FOR SOLID ROUND GLASS FIBRE REINFORCED POLYMER (GFRP) BARS FOR CONCRETE REINFORCEMENT (*Concluded*)

PART B — TEST RESULTS

Mechanical and Durability Properties of GFRP Bars

GFRP bar		**Result**							**Requirements**
		S1	S2	S3	S4	S5	Average	CoV[1)]	
Lot No.									
Glass fibre content (percent)									≥ 75
Glass transition temperature (°C)									≥ 100
Degree of cure (percent)									≥ 95
Cross-sectional area (mm^2)									As per Table 1 of IS 18256
Ultimate tensile force (kN)									As per Table 1 of IS 18256
Tensile modulus of elasticity (GPa)									≥ 45
Ultimate tensile strain									≥ 1.1
Transverse shear strength (MPa)									≥ 130
Bond strength (MPa)									≥ 7.6
Residual fatigue tensile strength[2)] (percent)									≥ 60
Ultimate tensile strength of bent bar[3)] (percent)									≥ 60 percent of ultimate tensile strength of straight bar
Creep failure[2)]									No rupture
Water absorption (percent)	Short								≤ 0.25
	Long								≤ 1.0
Ultimate tensile strength after 90 days of exposure to alkaline solution (percent)									≥ 80 percent of ultimate tensile strength of pristine bar
Longitudinal wicking									No voids

1) Requirement for coefficient of variation (COV) of the properties tested: ≤ 0.1.
2) Applicable only if creep and fatigue tests are done.
3) Applicable only in case of bent bars.

NOTE — S1 to S5 refers to specimen numbers.

Tests performed by (Name, signature and date):

Authorised signatory (Name, signature, and date):

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ANNEX B

(*Clause* 4.3.1.2)

TYPICAL CHEMICAL AND PHYSICAL PROPERTIES OF GLASS FIBRES

B-1 A comparison of the chemical compositions and physical properties of the various types of glass fibres used for manufacturing GFRP bars are given in Table 5 and Table 6, respectively for information only.

Table 5 Typical Chemical Composition of Various Types of Glass Fibres

(*Clause* B-1)

Sl No.	Component	Percent	
		R Glass	E-CR Glass
(1)	(2)	(3)	(4)
i)	SiO_2	60	54 to 62
ii)	Al_2O_3	25	12 to 13
iii)	CaO	14	21
iv)	MgO	3	4.5
v)	B_2O_3	< 1	< 0.1
vi)	K_2O	< 1	0.6
vii)	Na_2O	-	-
viii)	ZrO_2	-	-

Table 6 Typical Physical Properties of Various Types of Glass Fibres

(*Clause* B-1)

Sl No.	Properties	R Glass	E-CR Glass
(1)	(2)	(3)	(4)
i)	Density, in g/cm^3	2.59	2.72
ii)	Tensile strength, in MPa	4 600	3 440
iii)	Modulus of elasticity, in MPa	89 500	80 000
iv)	Ultimate strain, in percent	< 4	< 4.8
v)	Coefficient of thermal expansion (x10^{-6}/°C)	4.1	5.9
vi)	Softening temperature, in °C	980	880

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ANNEX C

(*Clause* 11.1)

GENERAL GUIDELINES FOR HANDLING AND STORAGE OF GFRP BARS

C-1 The general handling and storage guidelines for GFRP bars shall be as given below:

a) Use heavy duty (leather) gloves while handling GFRP reinforcing bar as the fibres present in GFRP bars can cause splinters, cuts, and skin irritation. Wear safety glasses and dust masks while cutting the GFRP bar.

b) Do not shear the bars while cutting as this typically causes matrix cracking and fibre damage. Avoid unnecessary abrasion of GFRP bars by dragging or rubbing against other bars, as this may degrade their tensile strength and adversely affect the surface characteristics.

c) GFRP bars should be kept clean and free of oil, dust, chemicals, or other contaminants. Certain specific chemicals [such as methyl ethyl ketones, carbon disulphide, gasoline, solvents (for certain polymers)] can damage GFRP bars. Hence, such chemical exposure should be avoided.

d) GFRP bars should not be stored directly on the ground. It should be placed on timber pallets (to avoid dirt and mud) to ensure cleanliness and easy handling.

e) Avoid walking over the GFRP bars as it can damage the surface. Avoid surface damage/deep scoring on GFRP bar surface during handling/placement, as it will reduce their durability and load carrying capacity. Avoid dropping of shovel/ construction equipment on GFRP rebar surface.

f) Store the GFRP bars carefully and protect against deformation, heating, and exposure to sunlight/ultraviolet rays, which can degrade the GFRP bars. Hence, GFRP bars shall be supplied in UV resistant stretch wrap. Also, when exposed to temperatures above 50 °C and stored outdoors, GFRP bars should be covered with opaque covering materials.

g) Lift the bundles of bars with multiple points. Use spreader bars needed to prevent excessive bending of bundles.

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ANNEX D

(*Foreword*)

COMMITTEE COMPOSITION

Concrete Reinforcement Sectional Committee, CED 54

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